Sector S: Storm Surge

PROJECT FOR THE COMPREHENSIVE FLOOD MANAGEMENT PLAN FOR THE CHAO PHRAYA RIVER BASIN

FINAL REPORT
VOLUME 3: SUPPORTING REPORT

SECTOR S: TABLE OF CONTENTS

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CHAPTER S1 OBJECTIVE OF THE STUDY ON STORM SURGE

The objective of this study is to analyze storm surges at the Gulf of Thailand with simulations and utilize the results to Comprehensive Flood Management Plan in the Chao Phraya River Basin.

CHAPTER S2 TARGET AREA

The target area is at the Gulf of Thailand including the estuary of Chao Phraya River.

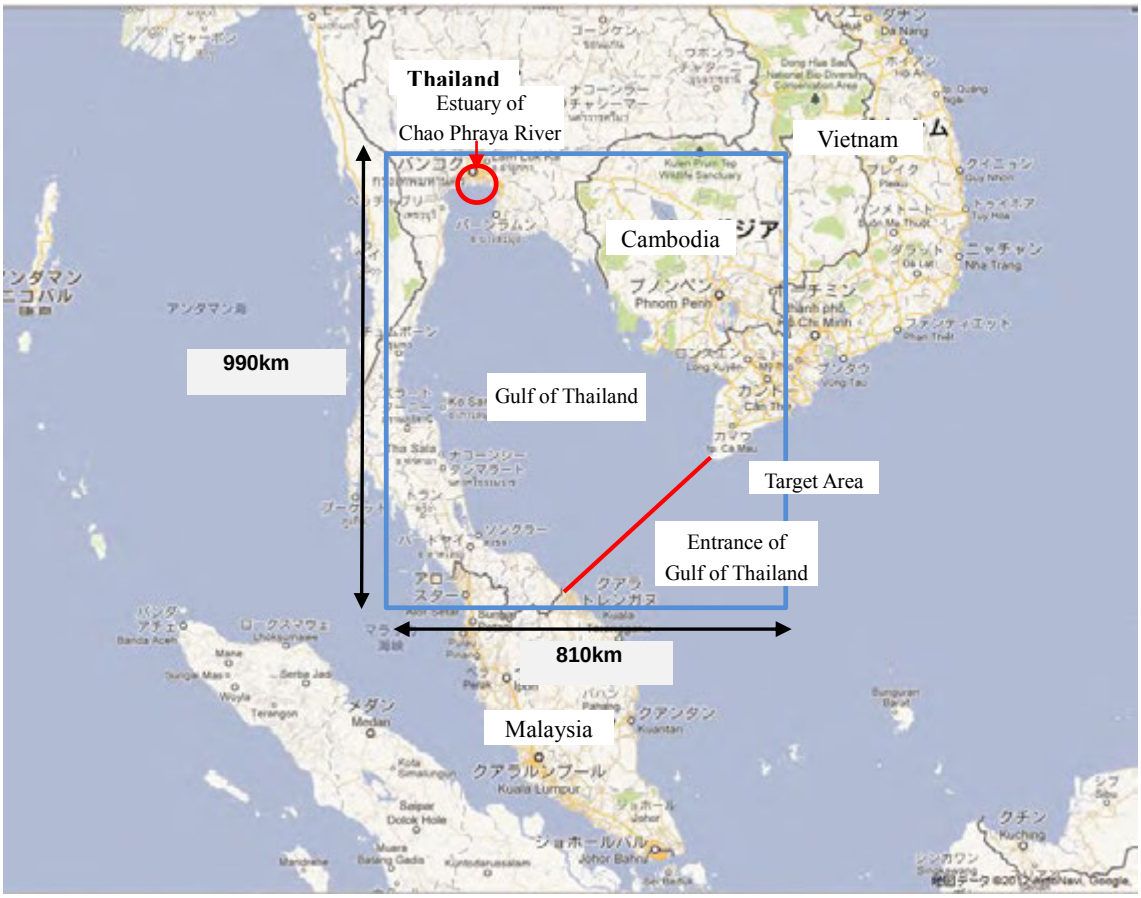


Figure S2.1.1 Target Area (Red Circle: Estuary of Chao Phraya River)

CHAPTER S3 MODELING

The following clause explains the concept of modeling.

S3.1 Concept of model

- high tide model: non-linear long wave theory
- typhoon model (Myers): atmospheric pressure, gradient velocity were calculated by the following equations

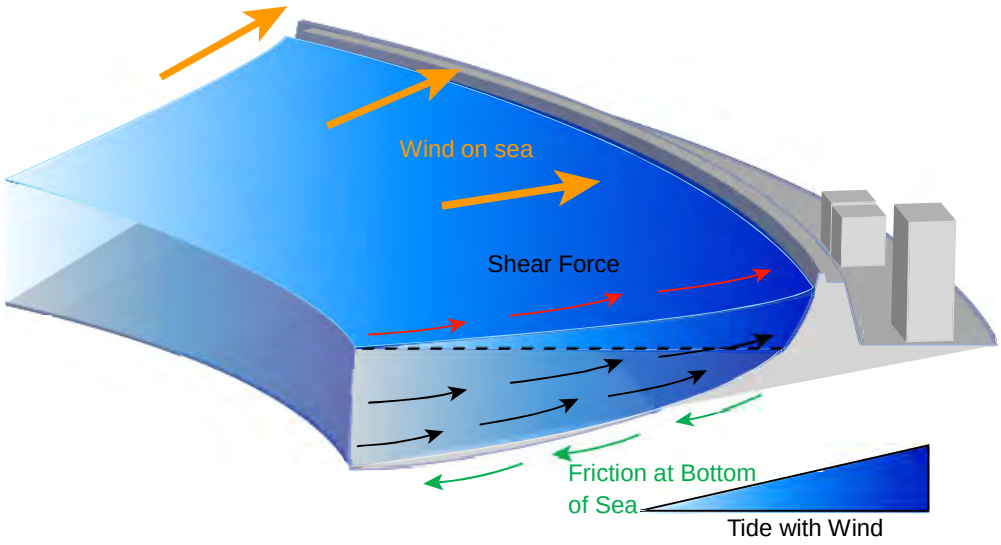


Figure S3.1.1 Typhoon Blowing Effect

1) Atmospheric pressure

$$p_a = p_\infty - \Delta p_0 \left\{ 1 - \exp\left(-\frac{r_0}{r} \right) \right\}$$

2) Gradient velocity

$$U_G = (rf/2)\left[-1 + \left\{ 1 + (4/\rho_a r f^2)\partial p_a / \partial r \right\}^{1/2} \right]$$

S3.2 Terrain model

The size of the target area is at 810km in east-west direction and at 990km in north-south direction as shown in Figure S2.1.1 and it was divided into three parts in terms of the mesh division size. The largest mesh size was at 4,500m, the medium one was at 1,500m and the smallest one was at 500m.

The terrain model was constructed with the elevation data in SRTM30 PLUS (http://topex.ucsd.edu/WWW_html/srtm30_plus.html) ,which is open to public. Figure S3.2.1 shows the model mesh at the target area. Figure S3.2.2 and Figure S3.2.3 and Figure S3.2.4 show the elevations in the large mesh, medium mesh and the small mesh, respectively.

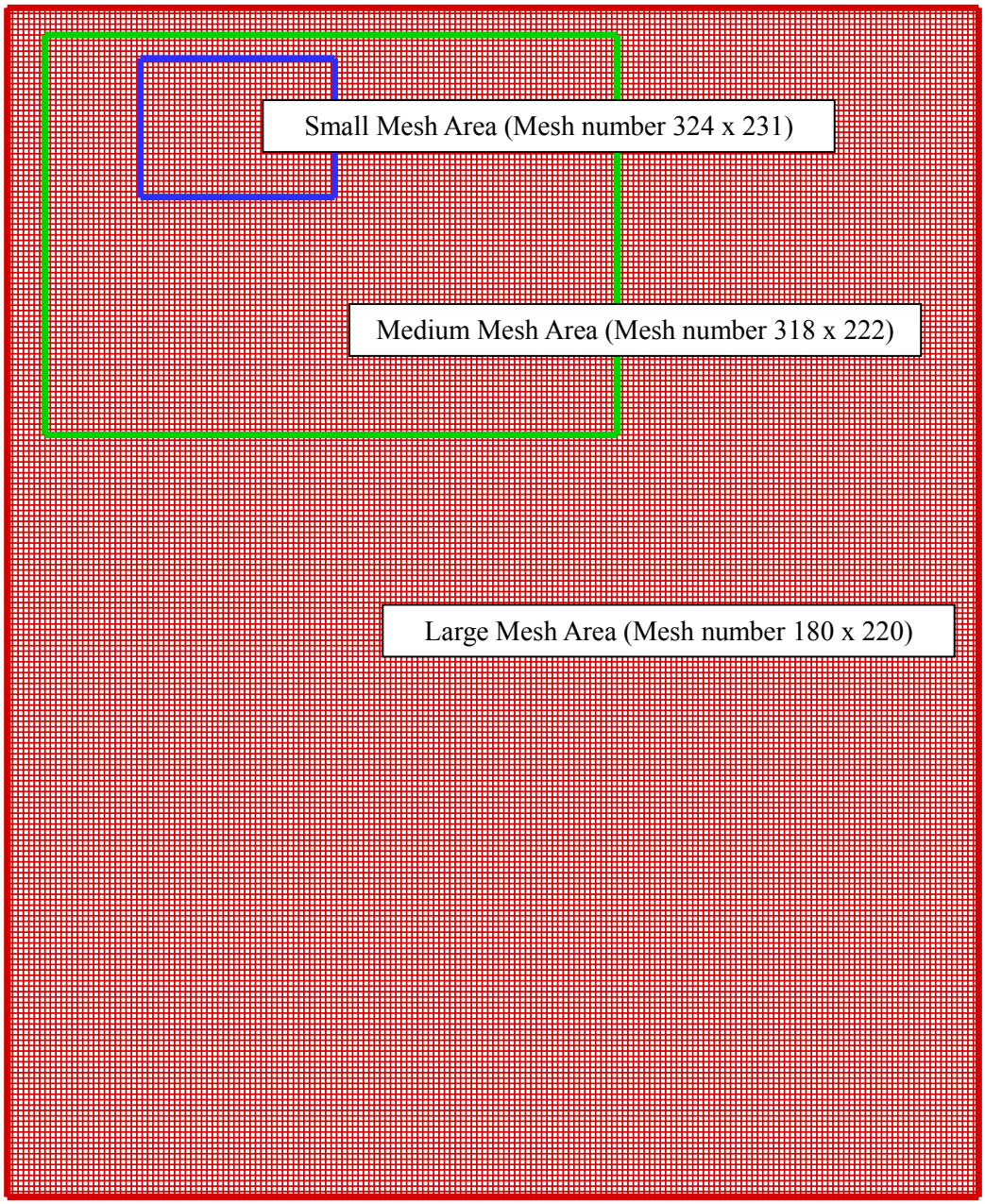


Figure S3.2.1 Mesh Division (Large, Medium and Small)

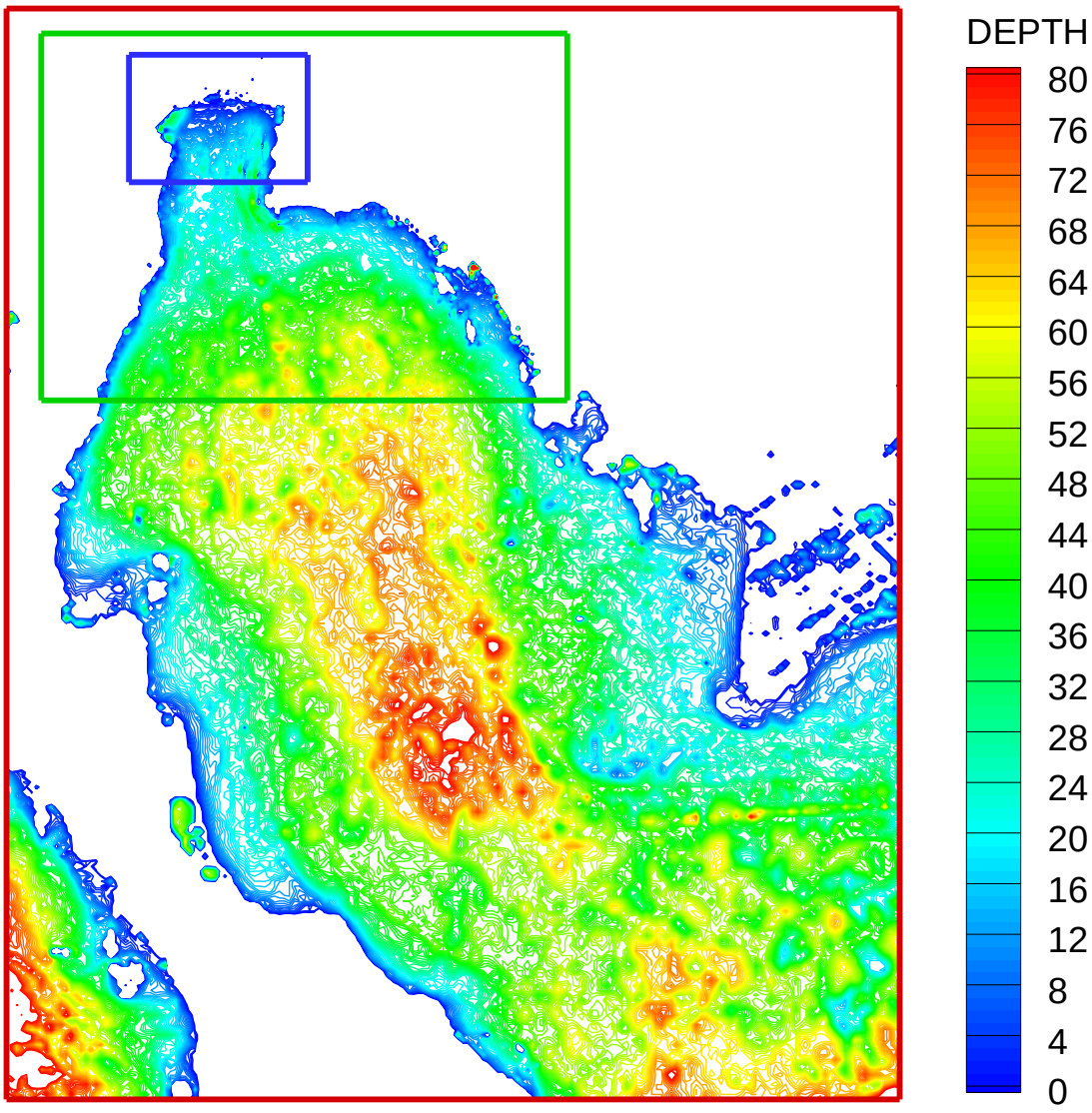
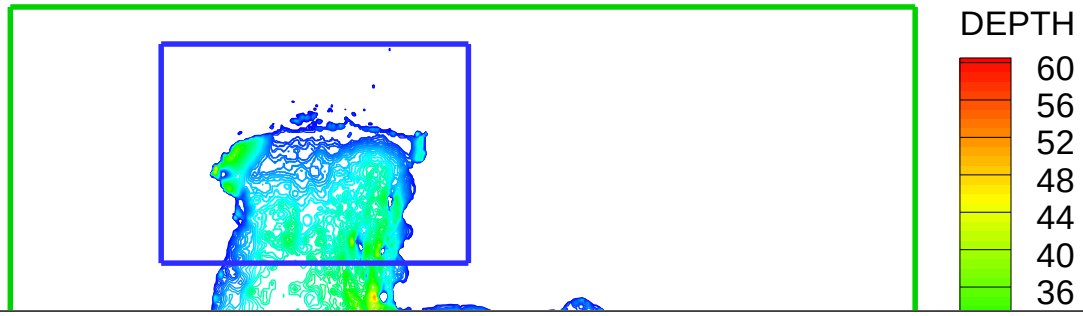


Figure S3.2.2 Terrain Map with Elevation (Large Mesh)



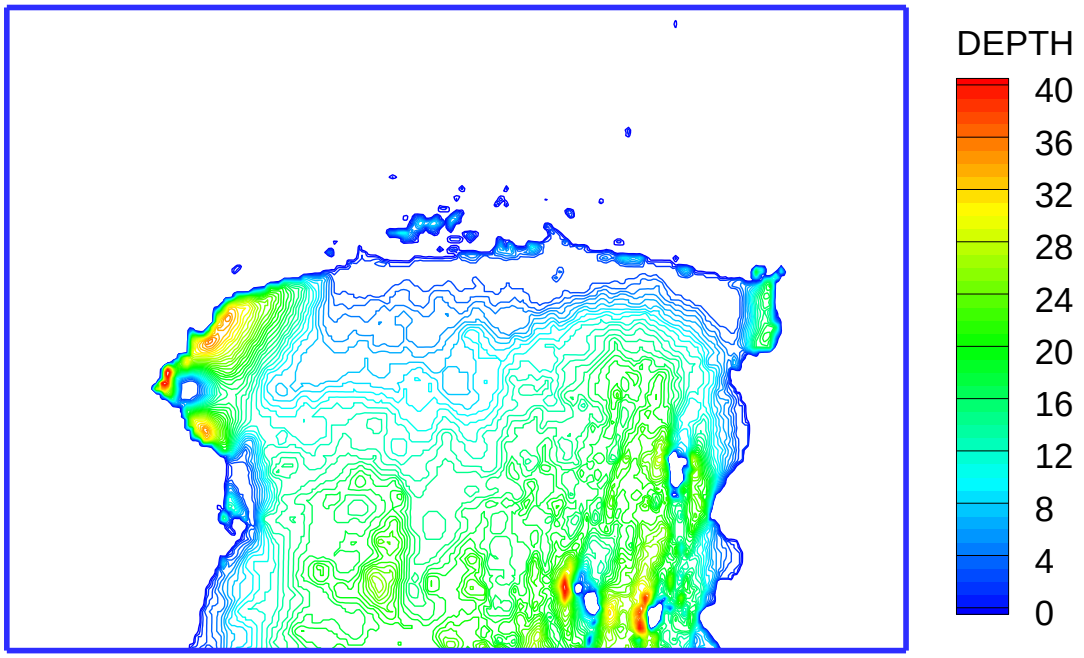


Figure S3.2.4 Terrain Map with Elevation (Small Mesh)

CHAPTER S4 CONDITION

(1) Boundary Condition (Land Side): Setting as reflection condition
(2) Boundary Condition (Sea Side): Setting offshore as penetration
(3) Structural Condition: Setting no coastal structure

S4.1 Case study

The three target typhoons were basically selected as follows. The more typhoon data may be added in the future if necessary. Since the atmospheric pressure and a radius of the tropical cyclone "Harriet" (1962) was not available as of February 1, 2013, following two typhoons were selected as the target typhoons, presently.

Tropical Cyclone "Harriet" (1962)
Typhoon "Gay" (1989)
Typhoon "Linda" (1997)

Figure S4.1.1 and Table S4.1.1 show the track, atmospheric pressure and the radius of Typhoon Gay (1989) and Figure S4.1.2 and Table S4.1.2 show the ones of Typhoon Linda (1997).

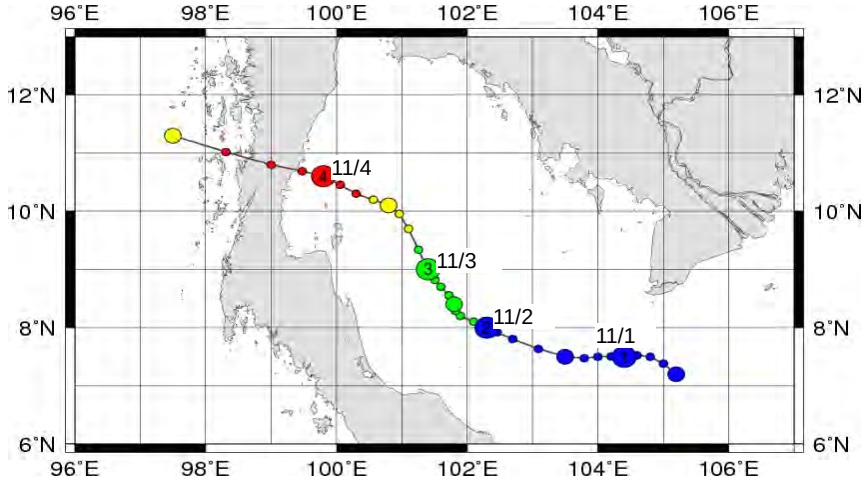


Figure S4.1.1 Track of Typhoon Gay

Table S4.1.1 Location, Atmospheric Pressure and Radius of Typhoon Gay

Date	East (°)	West (°)	Pressure* (hPa)	Radius (km)
89110207	102.000	8.000	11.0	171.5
89110212	102.100	8.100	15.0	171.5
89110215	101.900	8.200	19.0	205.8
89110221	101.800	8.400	19.0	205.8
89110303	101.600	8.700	21.0	205.8
89110309	101.400	9.000	23.0	205.8
89110315	101.100	9.700	33.0	274.4
89110321	100.800	10.100	38.0	343.0
89110403	100.300	10.300	43.0	343.0
89110409	99.800	10.600	53.0	343.0
89110415	99.000	10.800	43.0	343.0
89110421	97.500	11.300	38.0	343.0
89110427	96.800	11.700	38.0	343.0
89110433	95.700	11.800	38.0	343.0
89110439	94.800	12.000	38.0	343.0
89110601	94.000	12.400	38.0	343.0
89110607	92.500	12.600	38.0	343.0
89110613	91.500	12.700	38.0	343.0
89110619	90.600	13.500	38.0	343.0
89110701	88.800	13.600	38.0	343.0
89110707	88.100	13.900	38.0	343.0
89110713	87.100	14.200	38.0	343.0
89110719	86.200	14.600	38.0	343.0
89110801	85.100	14.700	38.0	343.0
89110807	83.500	14.800	38.0	343.0
89110813	82.800	15.000	38.0	343.0
89110819	82.000	15.200	38.0	343.0
89110901	80.400	15.200	38.0	343.0
89110907	79.800	15.500	38.0	343.0
89110913	78.000	15.700	38.0	343.0
89110919	76.700	15.600	38.0	343.0
89111001	74.900	15.300	38.0	343.0
89111007	73.400	15.500	38.0	343.0
89111013	72.300	16.000	38.0	343.0
89111019	72.000	16.000	38.0	343.0

Note: (Pressure) = 1000 - (Actual Pressure)
Source: http://agora.ex.nii.ac.jp/digital-typhoon/ "Digital Typhoon" Home Page

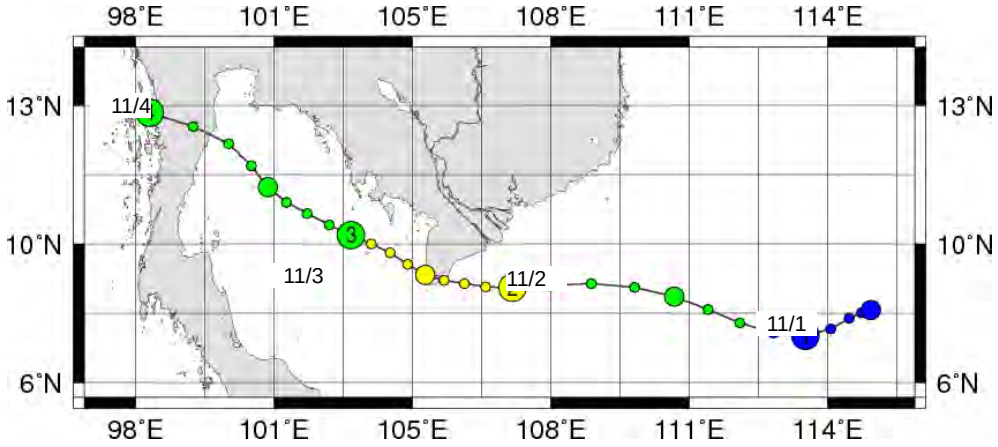


Figure S4.1.2 Track of Typhoon Linda

Table S4.1.2 Location, Atmospheric Pressure and Radius of Typhoon Linda

Date	East (°)	West (°)	Pressure* (hPa)	Radius (km)
97110101	115.000	8.000	7.0	222.2
97110107	112.000	8.300	11.0	222.2
97110115	112.000	7.700	17.0	222.2
97110121	110.500	8.300	19.0	222.2
97110203	108.600	8.600	21.0	240.8
97110209	106.800	8.500	28.0	240.8
97110215	105.700	8.600	28.0	240.8
97110221	104.800	8.800	28.0	240.8
97110303	104.000	9.300	28.0	240.8
97110309	103.100	9.700	23.0	240.8
97110315	102.100	10.200	23.0	222.2
97110321	101.200	10.800	21.0	203.7
97110403	100.300	11.800	15.0	185.2
97110409	98.500	12.500	15.0	185.2
97110415	97.500	12.800	23.0	185.2
97110421	96.500	13.000	17.0	185.2
97110501	95.500	13.200	17.0	185.2
97110507	94.800	13.600	5.0	185.2
97110513	94.300	13.900	7.0	185.2
97110519	93.800	14.500	7.0	185.2
97110601	93.000	15.100	7.0	185.2
97110607	92.300	15.500	9.0	185.2
97110613	92.100	15.500	7.0	185.2
97110619	92.100	15.500	7.0	185.2
97110701	92.100	15.500	9.0	185.2
97110707	92.100	15.500	9.0	185.2
97110713	92.100	15.500	7.0	185.2
97110719	92.000	15.500	7.0	185.2
97110801	92.000	15.500	7.0	185.2
97110807	92.000	15.500	7.0	185.2
97110813	92.000	15.500	3.0	185.2
97110819	92.000	15.500	3.0	185.2
97110901	92.000	15.000	5.0	185.2
97110907	92.000	15.500	5.0	185.2
97110913	91.500	15.000	5.0	185.2
97110919	91.000	15.000	7.0	185.2
97111001	90.500	15.000	1.0	185.2

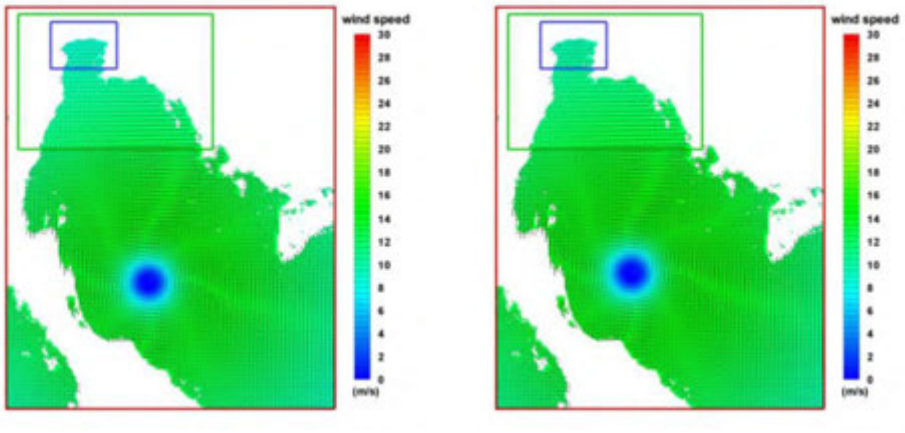
Note: (Pressure) = 1000 - (Actual Pressure)
Source: http://agora.ex.nii.ac.jp/digital-typhoon / “Digital Typhoon” Home Page

CHAPTER S5 RESULT (PLANAR DISTRIBUTION)

This clause shows the results of the storm surge analysis with Typhoon Gay and Typhoon Linda.

The results with Typhoon Gay were shown from Figure S5.1.1 to Figure S5.1.6 and then the results with Typhoon Linda were presented from Figure S5.1.7 to Figure S5.1.12 in terms of a wind speed, a sea level rise, a maximum sea level rise and a maximum flow velocity.

(1) Typhoon Gay (1989)



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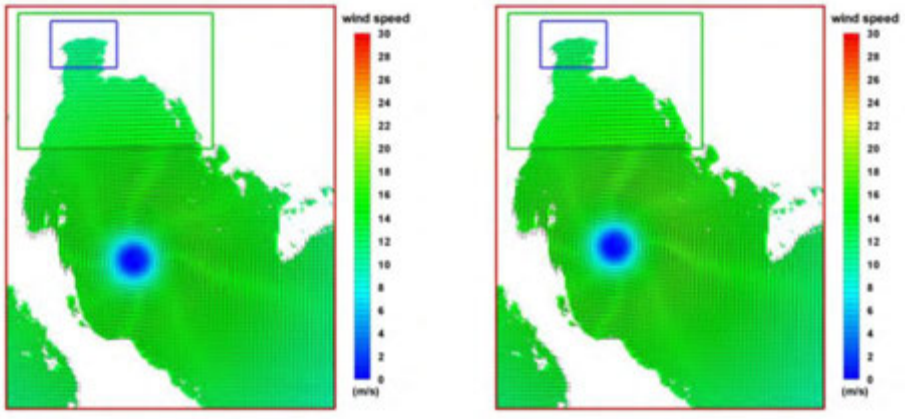

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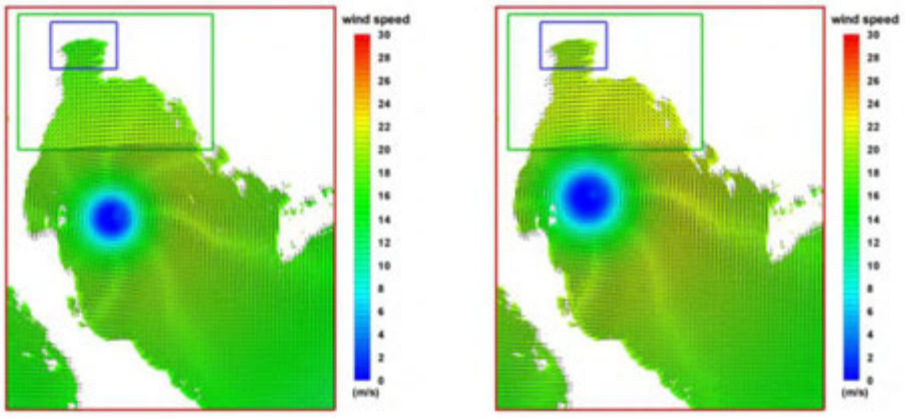

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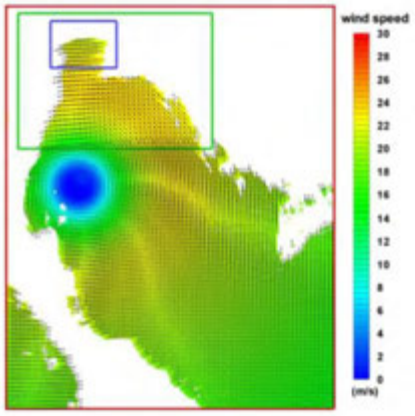
Figure S5.1.1 Wind Speed with Typhoon Gay (1/2)



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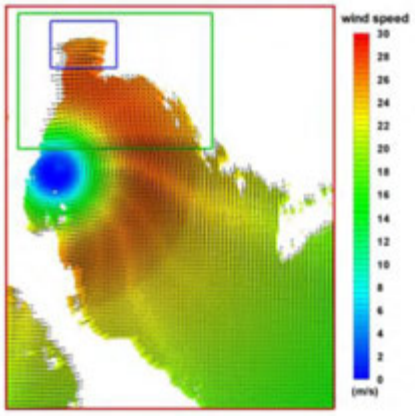

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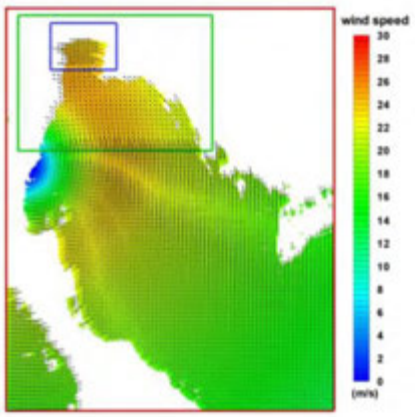

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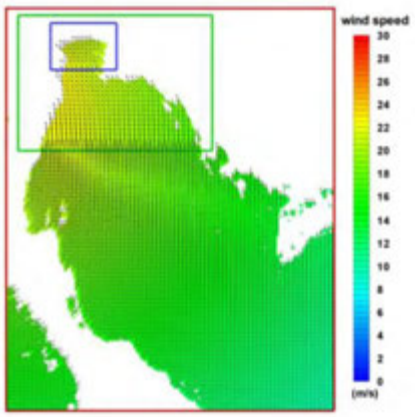

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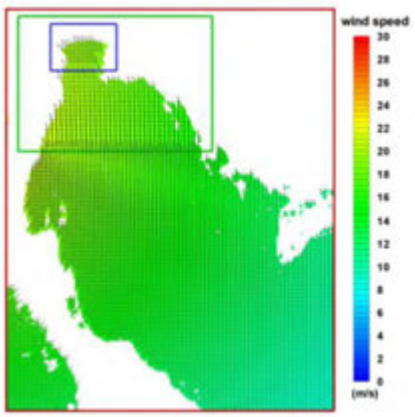

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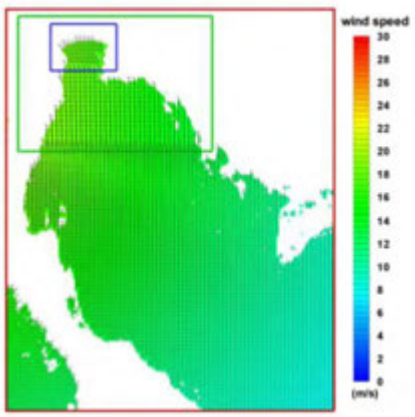

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Figure S5.1.2 Wind Speed Distribution with Typhoon Gay (2/2)

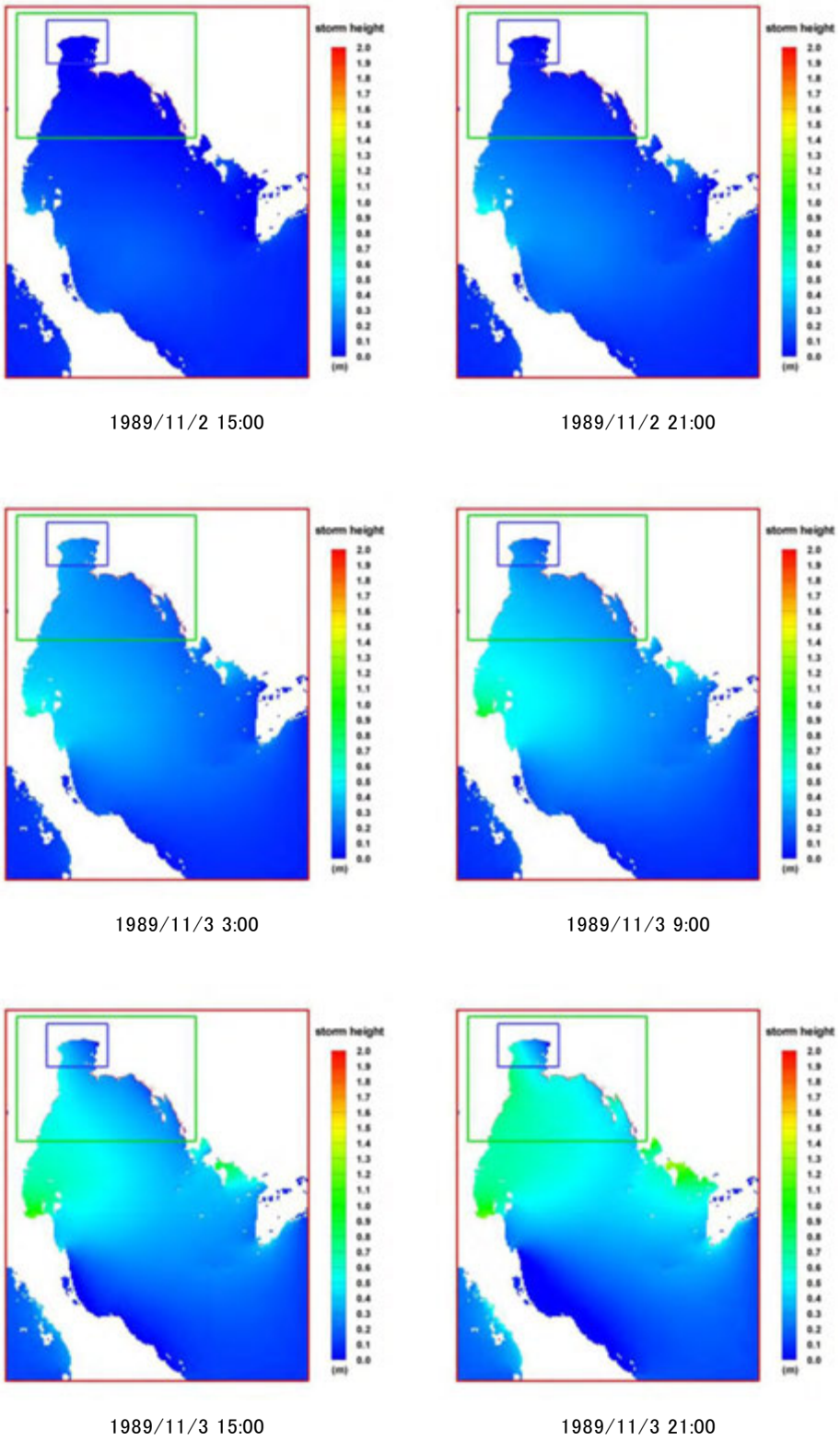
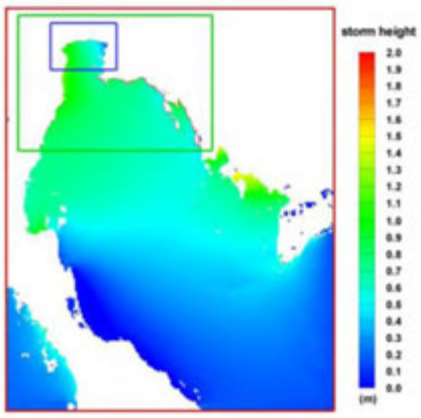


Figure S5.1.3 Sea Level Rise with Typhoon Gay (1/2)



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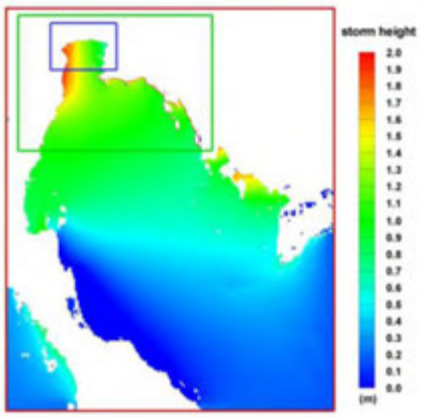

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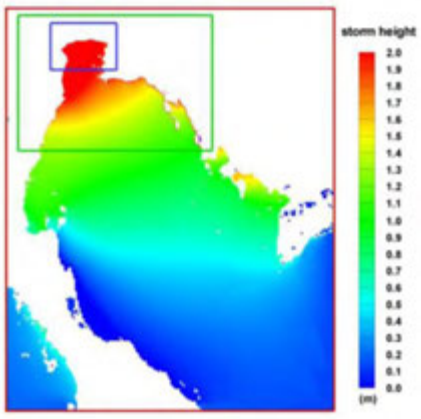

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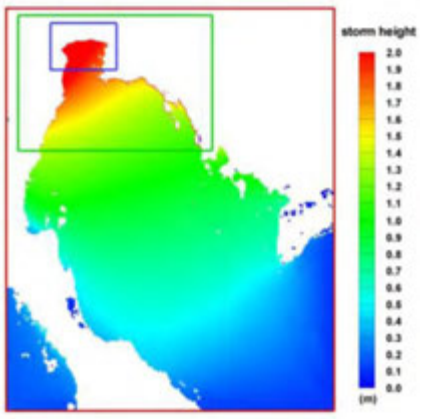

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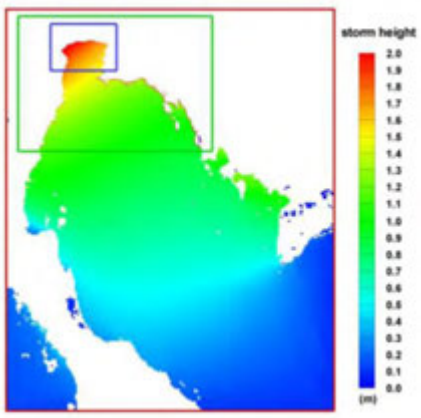

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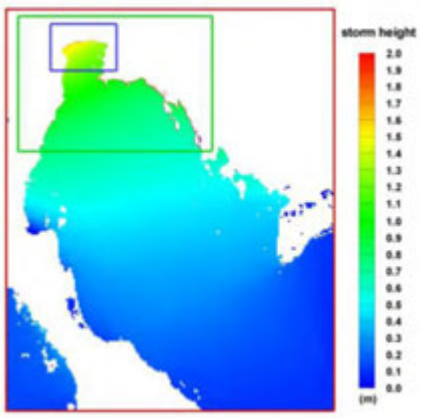

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Figure S5.1.4 Sea Level Rise with Typhoon Gay (2/2)

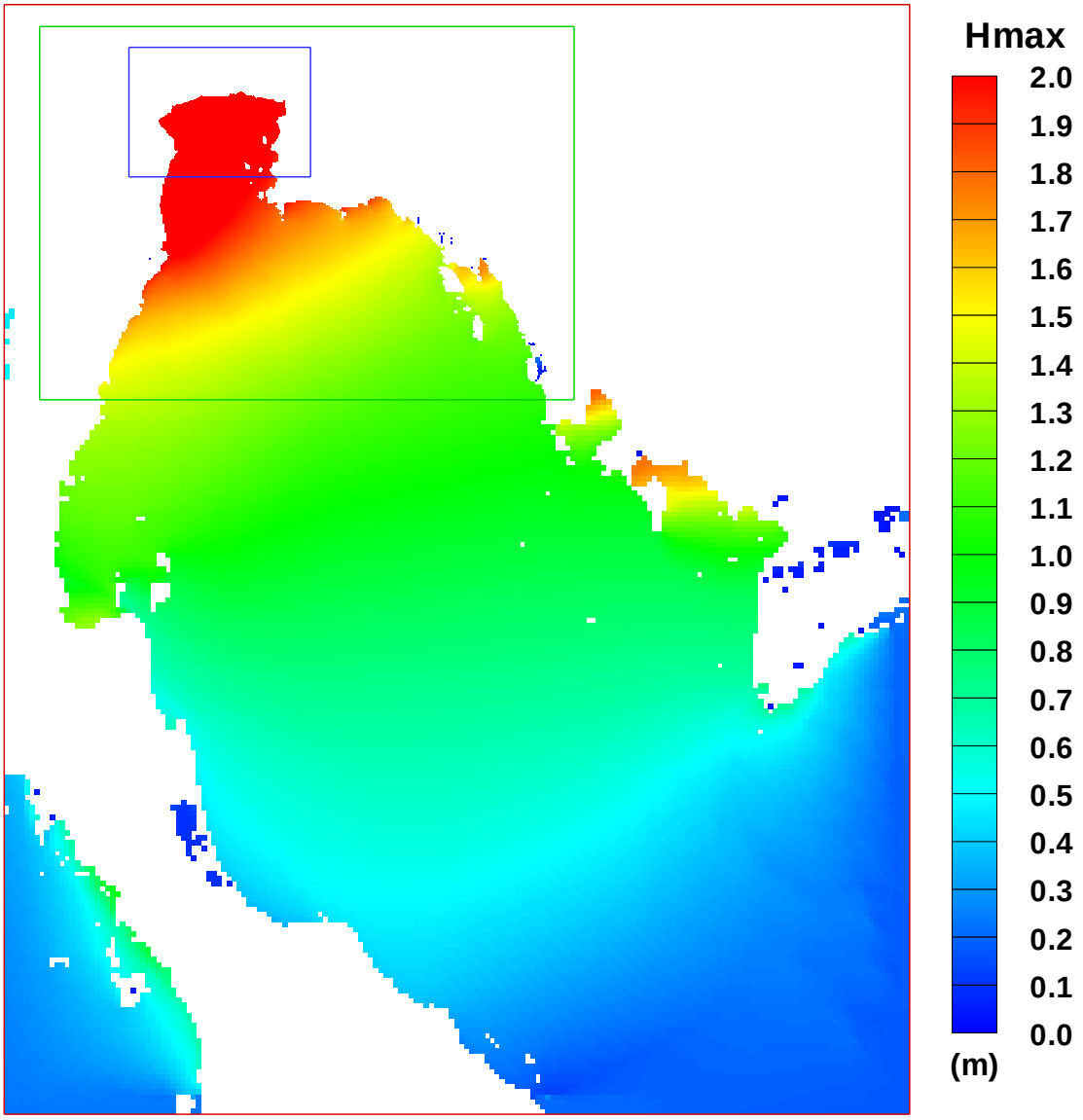


Figure S5.1.5 Maximum Sea Level Rise with Typhoon Gay

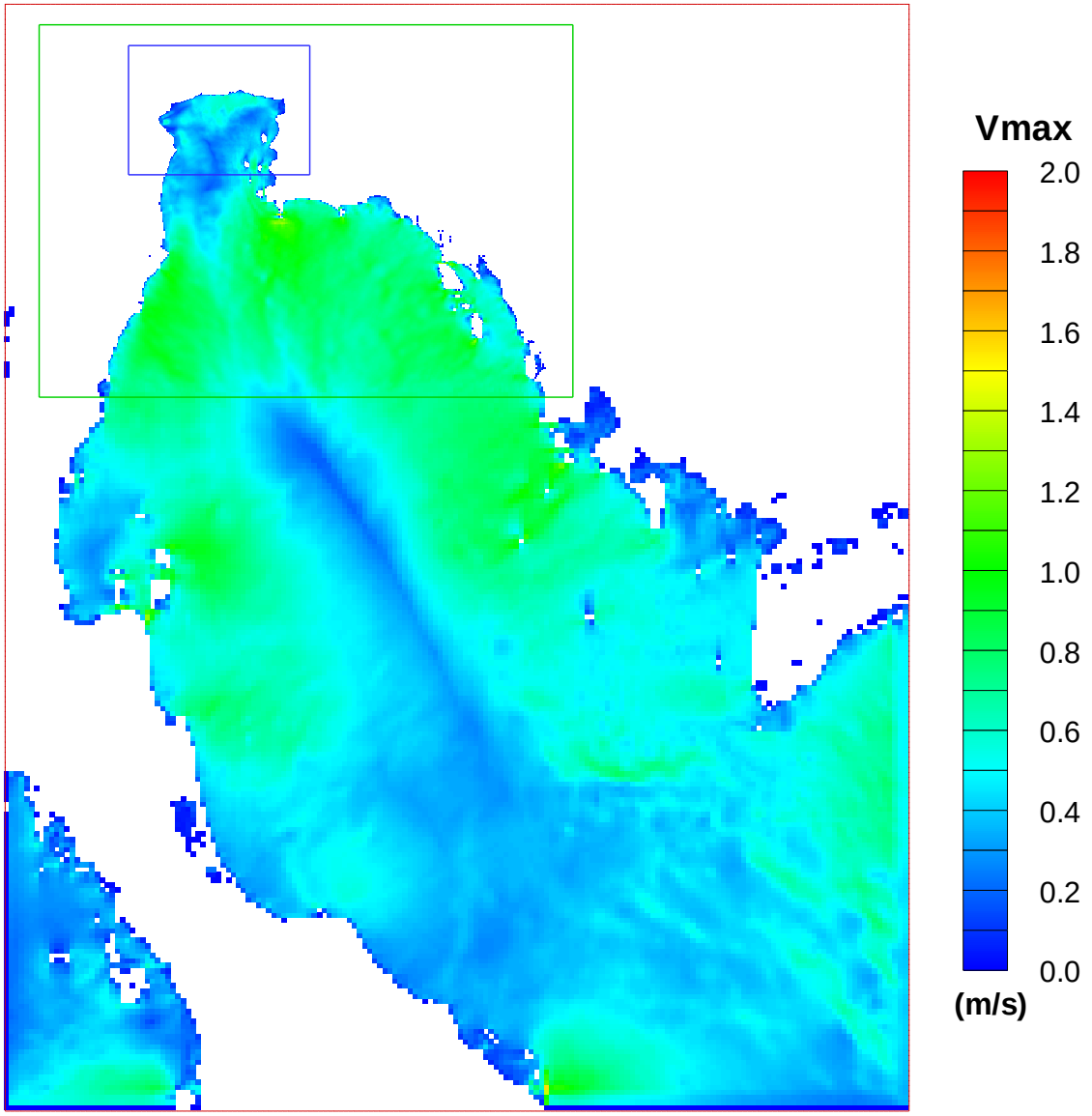


Figure S5.1.6 Maximum Flow Velocity with Typhoon Gay (1/2)

(2) Typhoon Linda (1997)

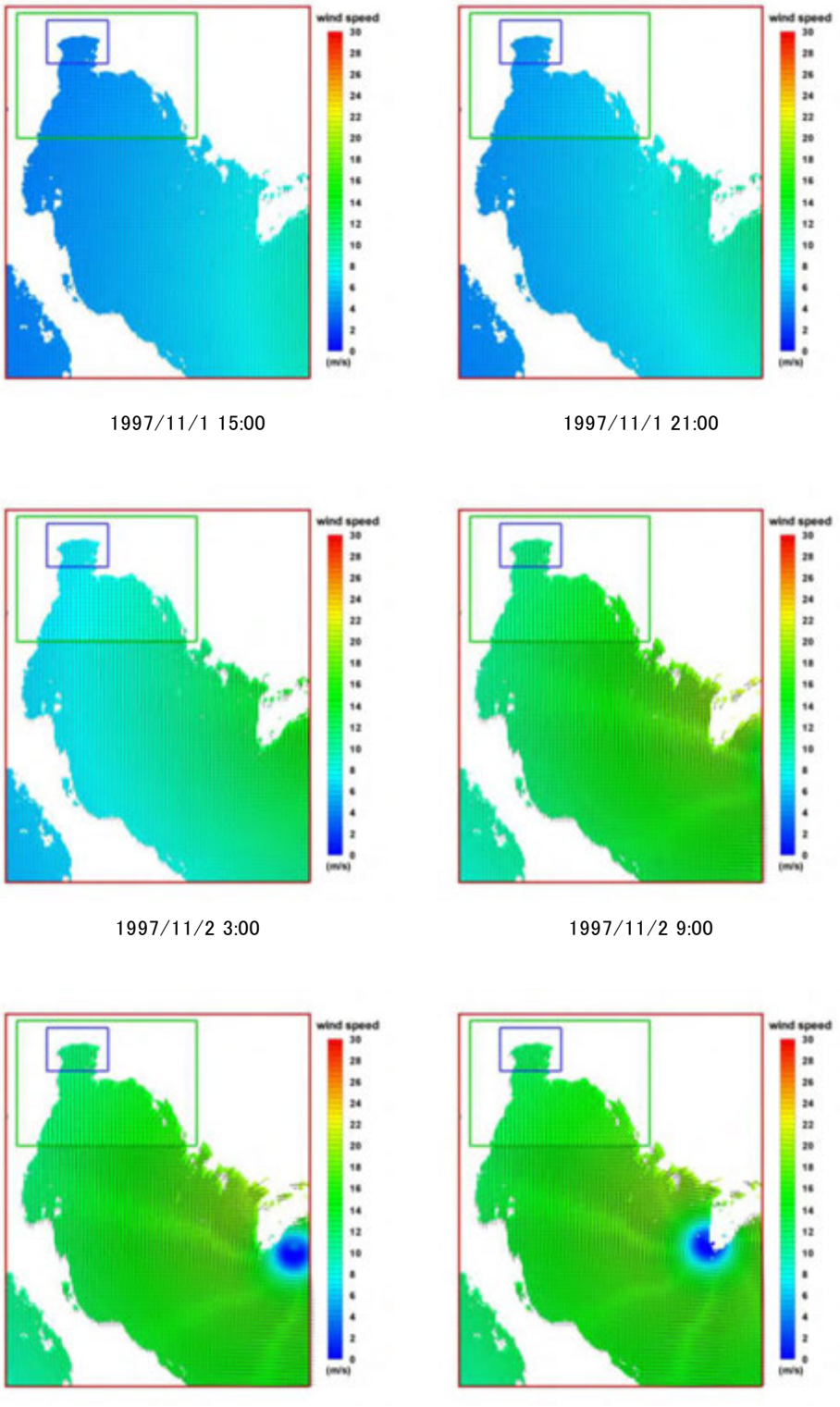
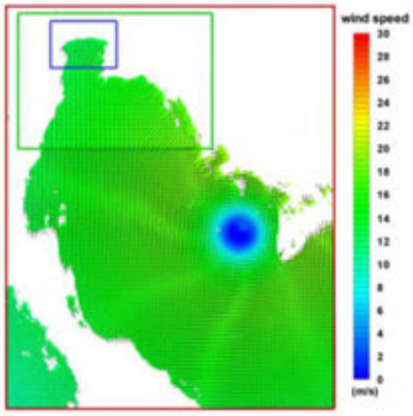


Figure S5.1.7 Wind Speed with Typhoon Linda (1/2)



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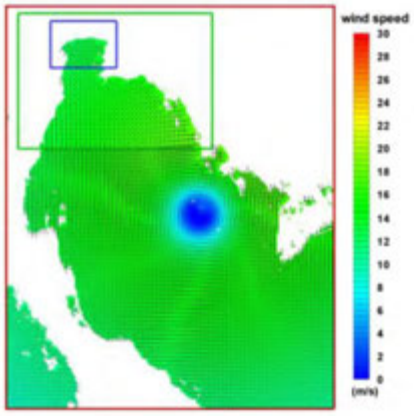

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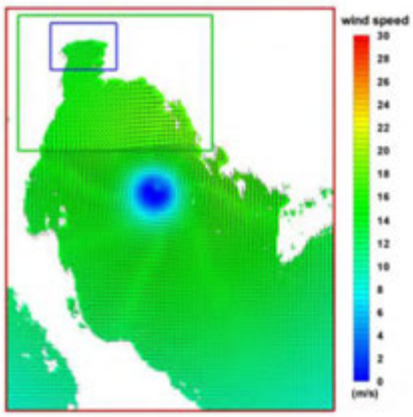

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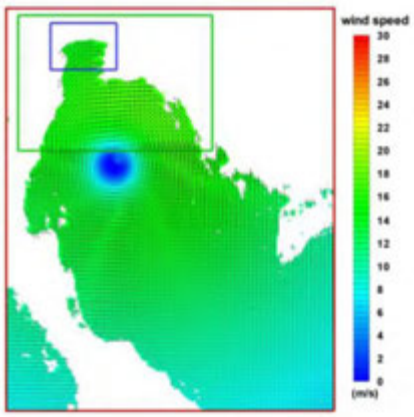

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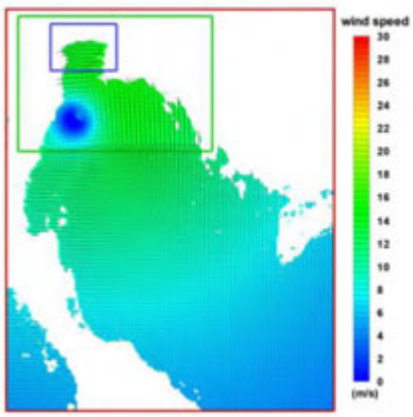

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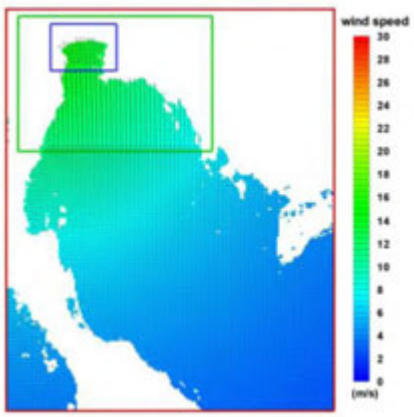

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Figure S5.1.8 Wind Speed with Typhoon Linda (2/2)

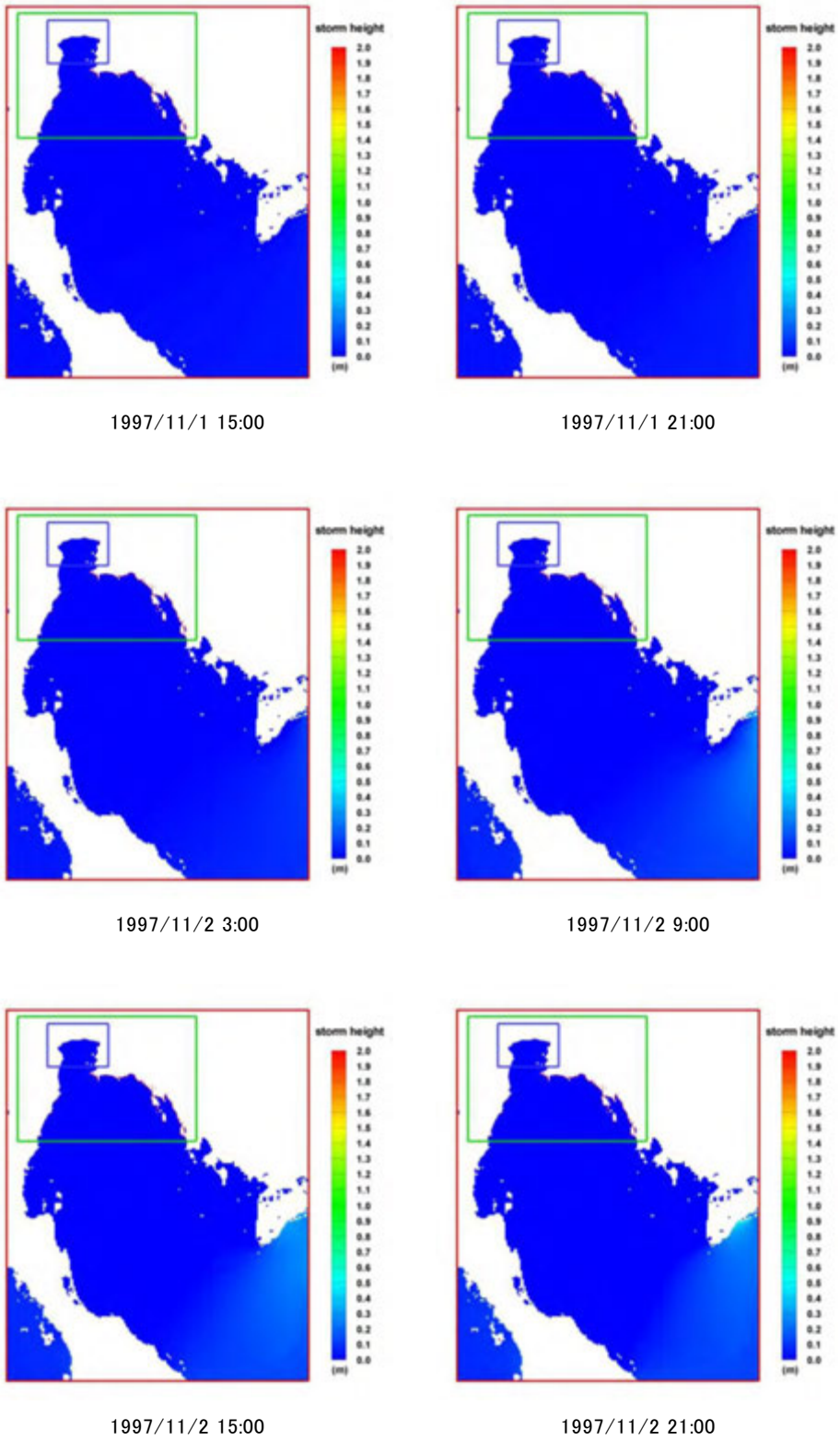
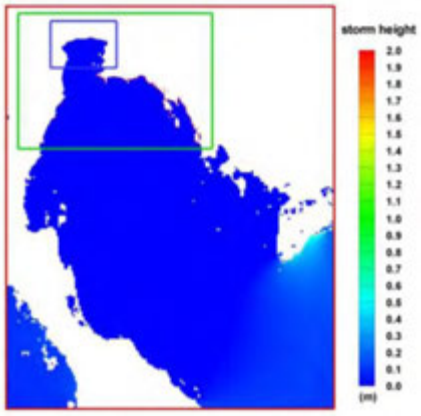


Figure S5.1.9 Sea Level Rise with Typhoon Linda (1/2)



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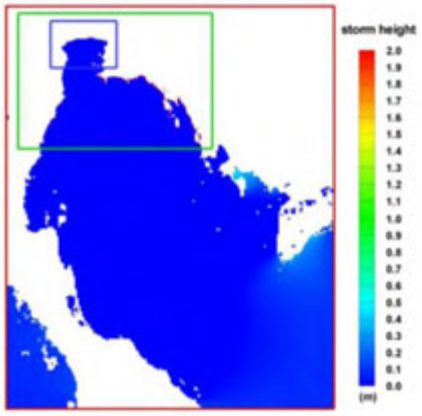

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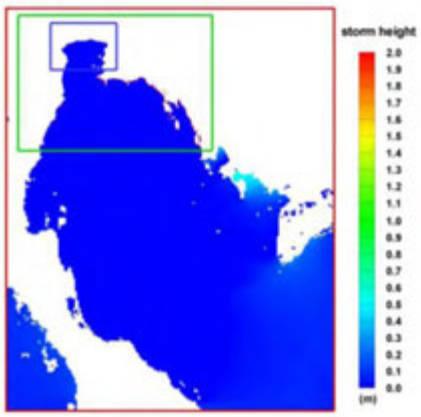

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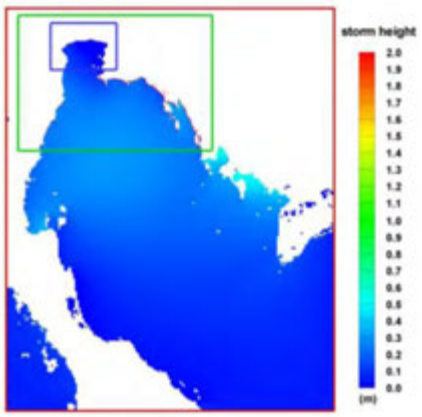

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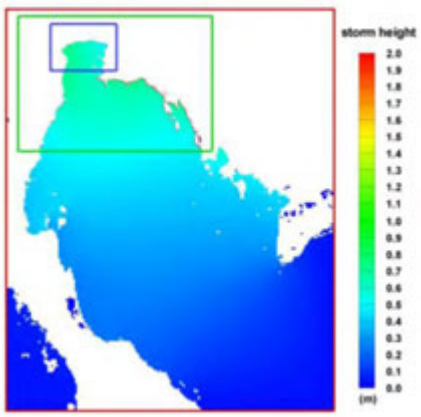

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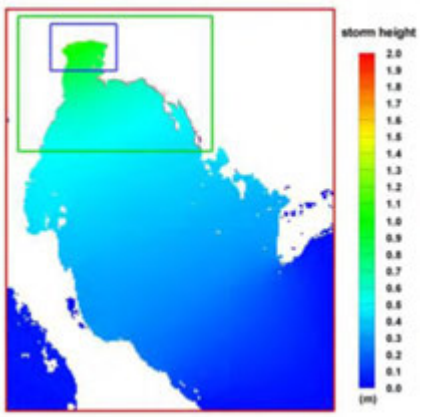

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Figure S5.1.10 Sea Level Rise with Typhoon Linda (2/2)

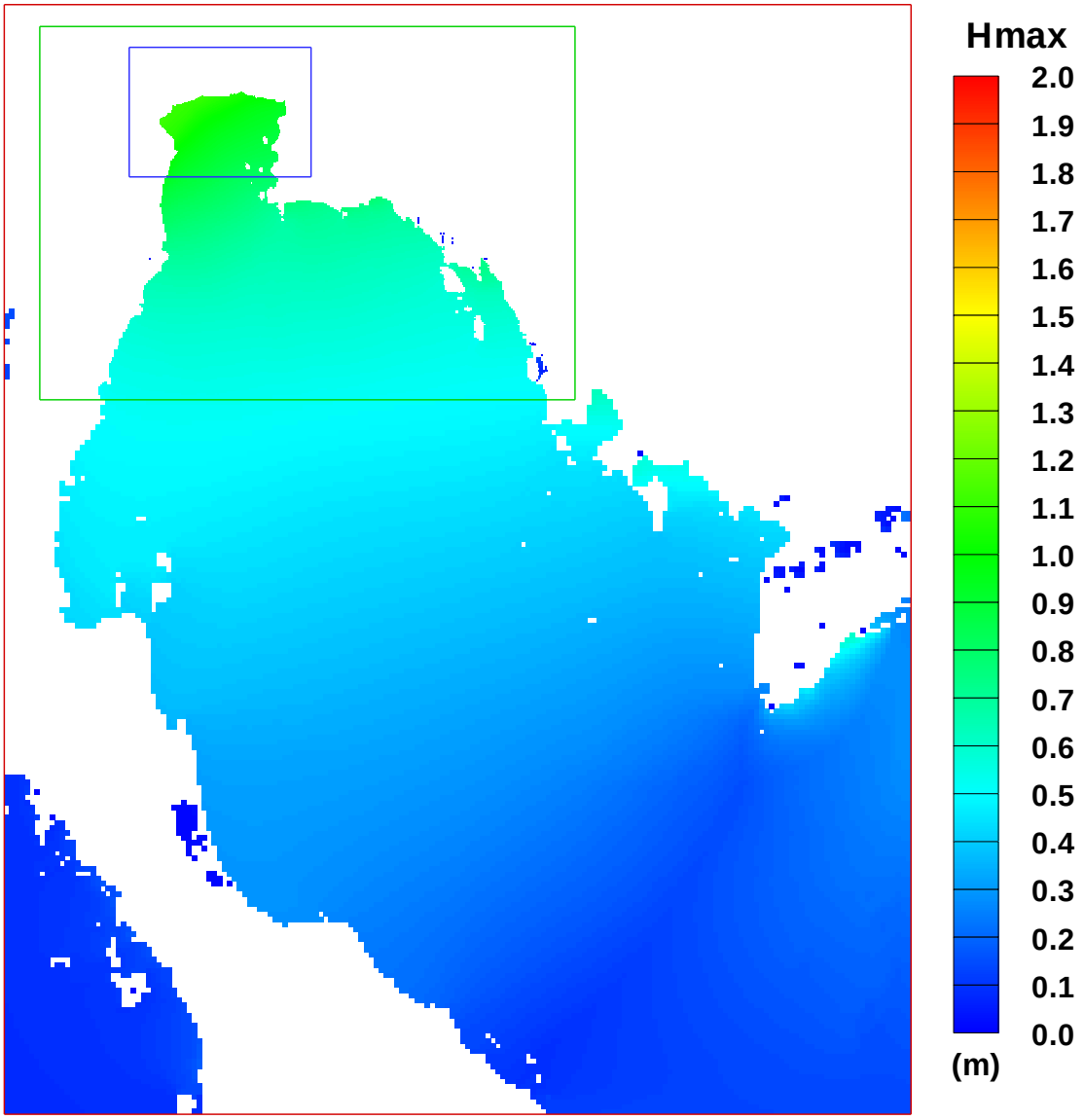


Figure S5.1.11 Maximum Sea Level Rise with Typhoon Linda

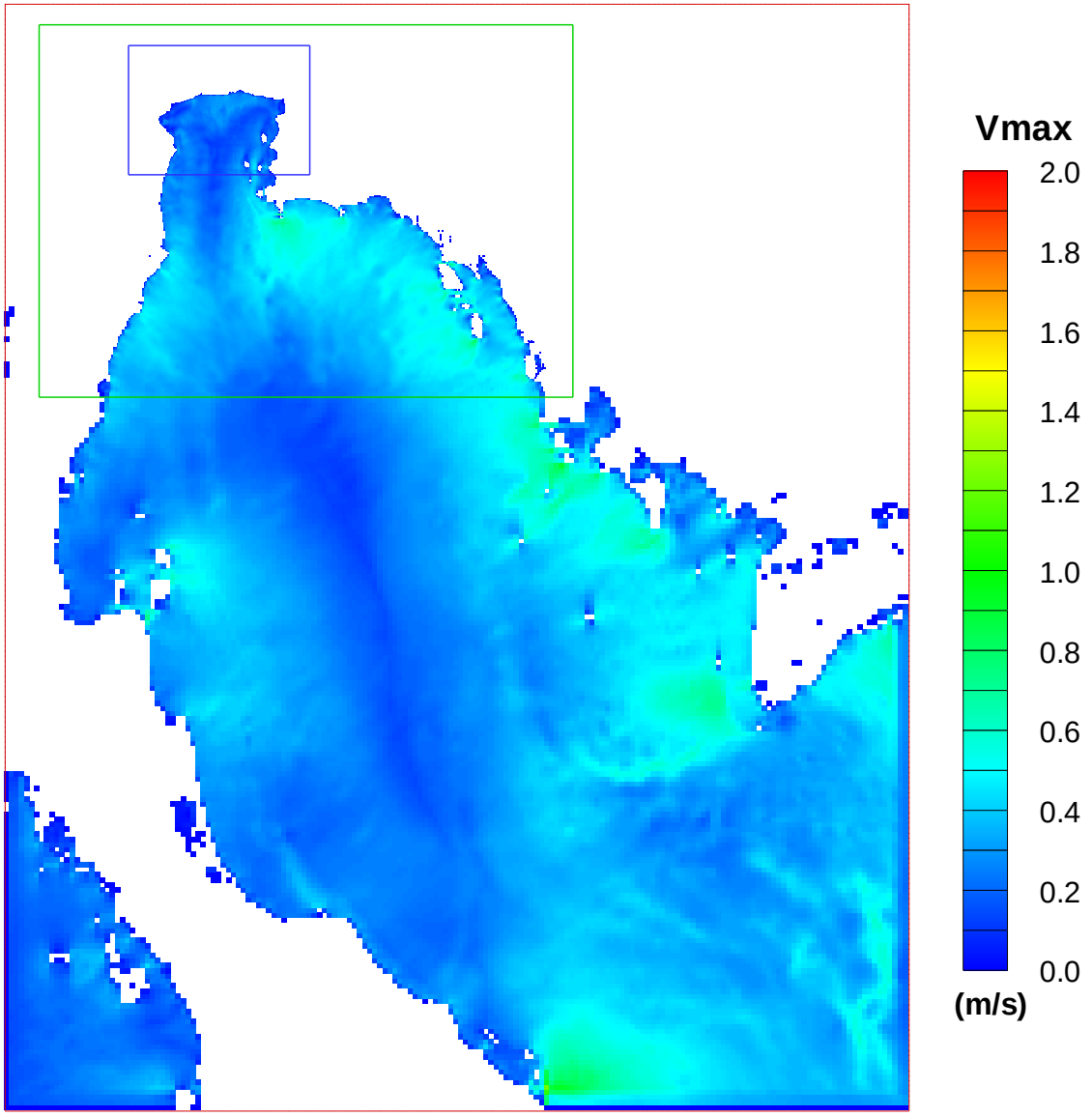


Figure S5.1.12 Maximum Flow Velocity with Typhoon Linda

CHAPTER S6 VERIFICATION RESULT (TIME-SERIES DATA)

The results of analyses were verified at the observation points of Marine Department shown in Figure S6.1.1 comparing the results and the observed data. Those results and data were expressed in height of the sea level and compared after subtracted by the astronomical tide level. Figure S6.1.2 and Figure S6.1.3 shows the results of comparisons with Typhoon Linda and with Typhoon Gay, respectively. Conditions of each data are as shown below.

1) Datum level for observed tide data: = M.S.L. + 2.5m
2) Datum level for astronomic tide level data: = M.S.L. + L.L.W. (see Table S6.1.1)
3) Standard time of observation data: = UTC + 7 hour (Thailand Standard Time)
4) Time zone in analyses: = UTC (Universal time coordinated)

Referring to the above mentioned conditions, the observed data were adjusted as follows.

1) Tidal datum level: M.S.L.
2) Time zone : UTC
3) Observed data: = (observed tide level data) - (astronomic tide level data)

Table S6.1.1 Datum Level at Tidal Station

Tidal Station	Lowest Low Water (L.L.W.) (unit: m)
1. Laem Ngop	1.78
2. Pak Nam Rayong	1.52
3. Ko Si Chang	2.48
4. Pak Nam Bang Pakong	1.67
5. Pak Nam Tha Chin	1.92
6. Pak Nam Mae Klong	2.14
7. Ko Samui	1.45
8. Pak Nam Pak Phanang	0.70
9. Pak Nam Pattani	0.78
10. Pak Nam Bang Nara	0.78

The verification results with Typhoon Linda (Figure S6.1.2) show that the analysis was performed adequately. In the case of the analyses with Typhoon Gay (Figure S6.1.3), the difference between the observed tide level and the astronomical tide level data was so small that it was impossible to evaluate the results of analyses. In addition, the observed data for Typhoon Gay was often missing. Then the accuracy of the observed data itself may have the uncertainty.

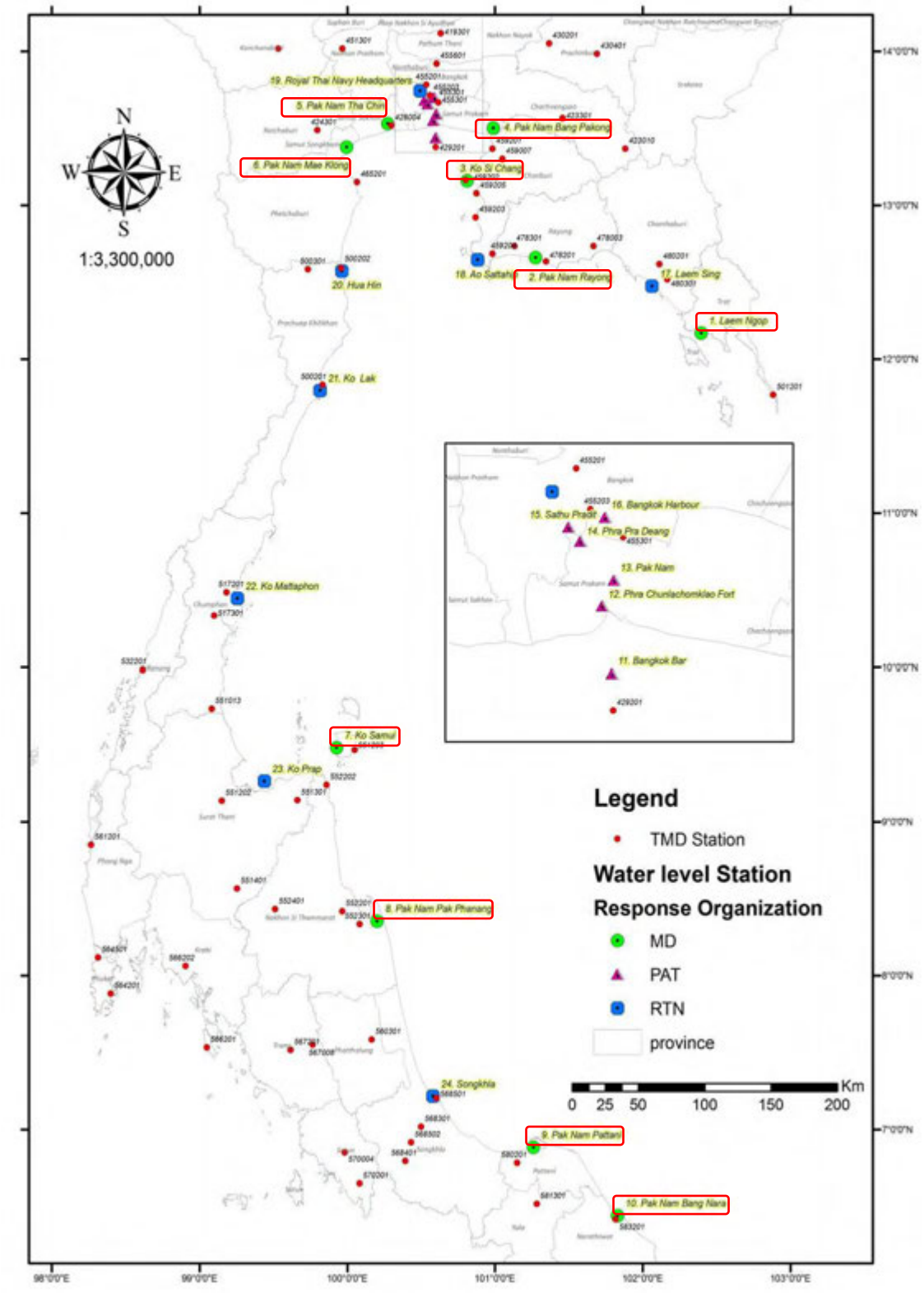
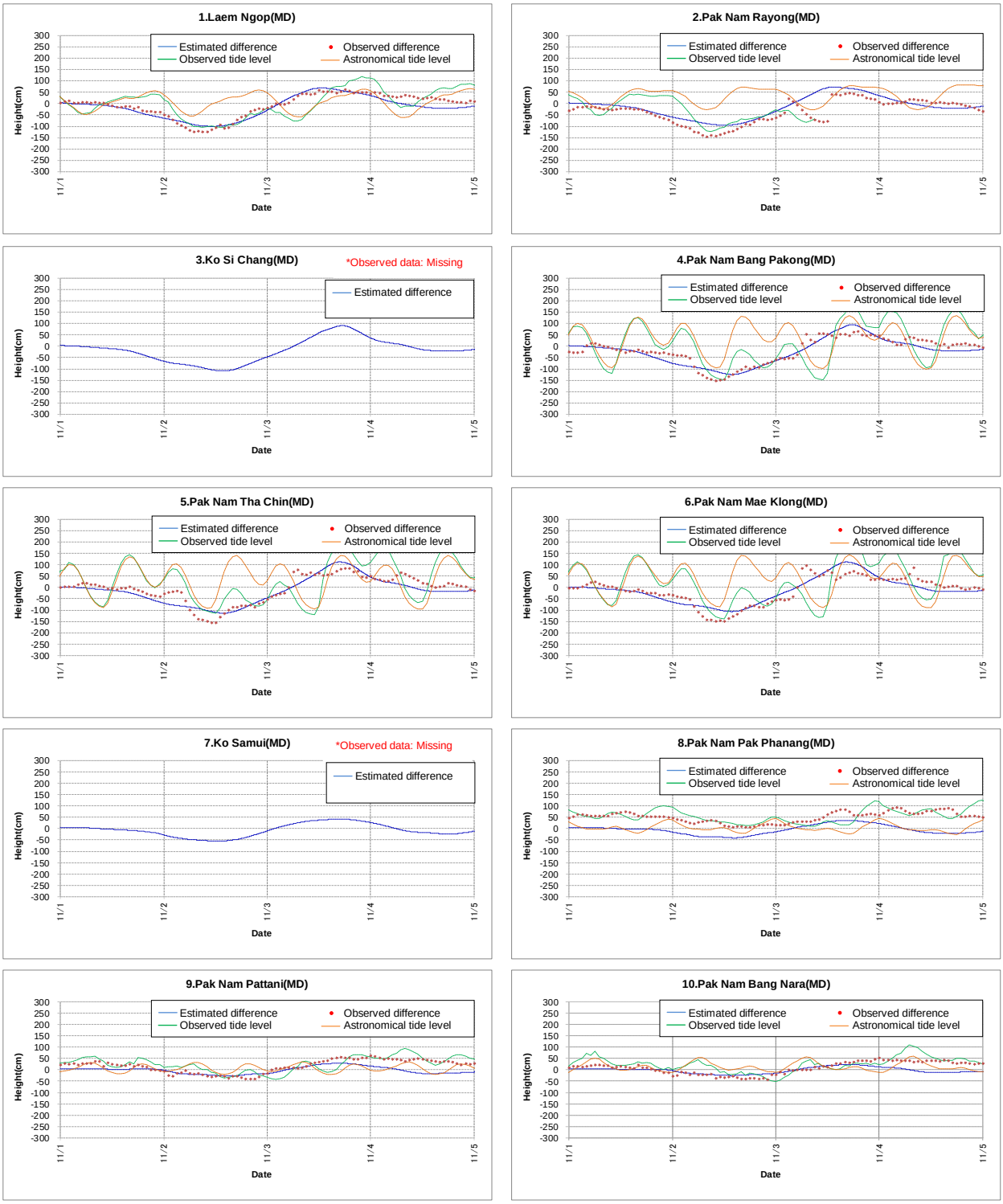


Figure S6.1.1 Comparison Points of Sea Level (with Red Rectangular)

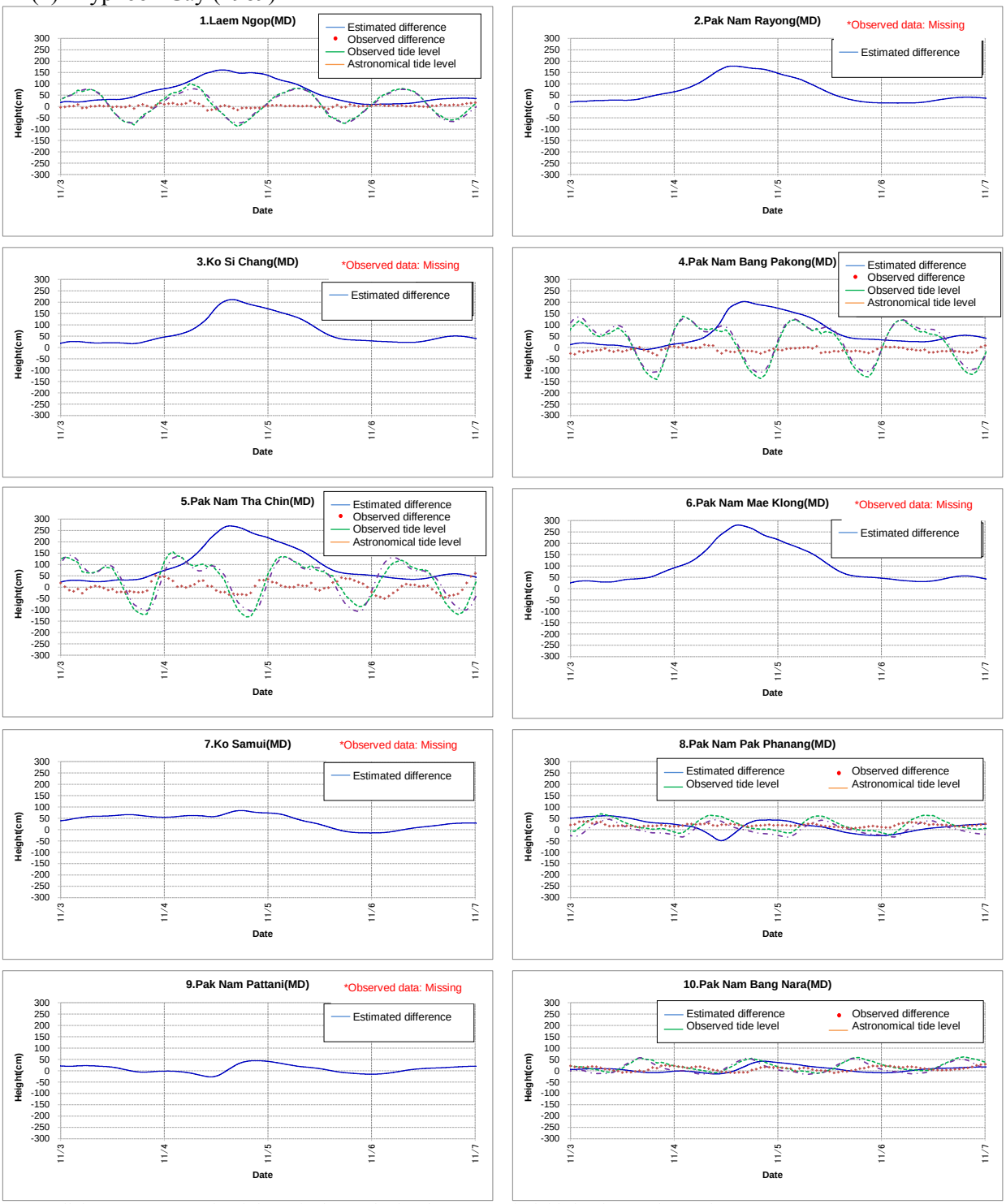
(1) Typhoon Linda (1997)



Note: All data were compared and shown in the graph after the astronomical tide level was subtracted.

Figure S6.1.2 Verification Result with Typhoon Linda

(2) Typhoon Gay (1989)



Note: All data were compared and shown in the graph after the astronomical tide level was subtracted.

Figure S6.1.3 Verification Result with Typhoon Gay

CHAPTER S7 STUDY ON DESIGN HIGH TIDE LEVEL

A simulation was performed in order to obtain the design high tide level.

S7.1 Track of typhoon

The track with Typhoon Linda was basically applied for this simulation. In order to see the more significant effect of typhoons, the track was bent to the north in the middle of Gulf of Thailand toward Chao Phraya River Basin.

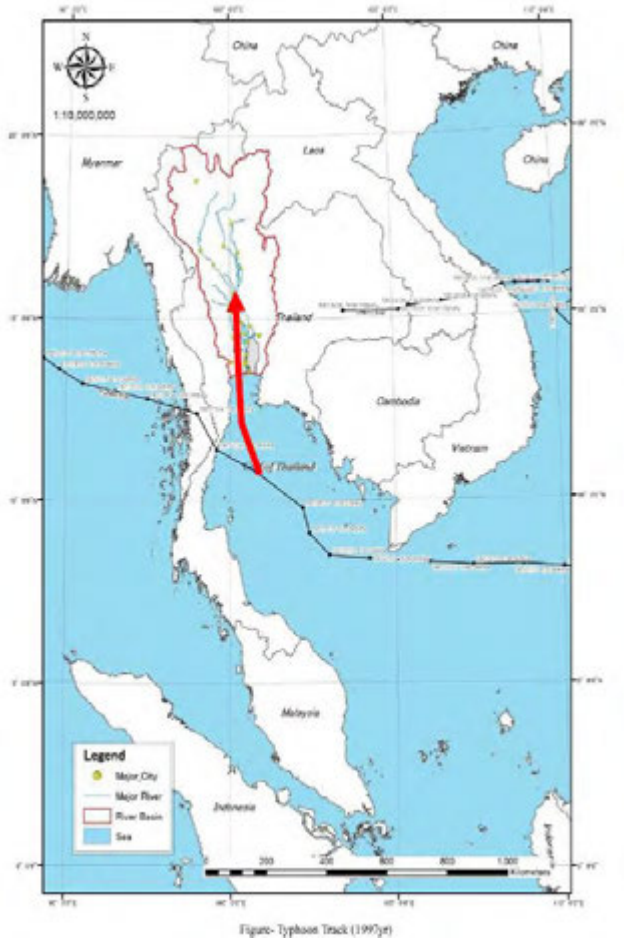
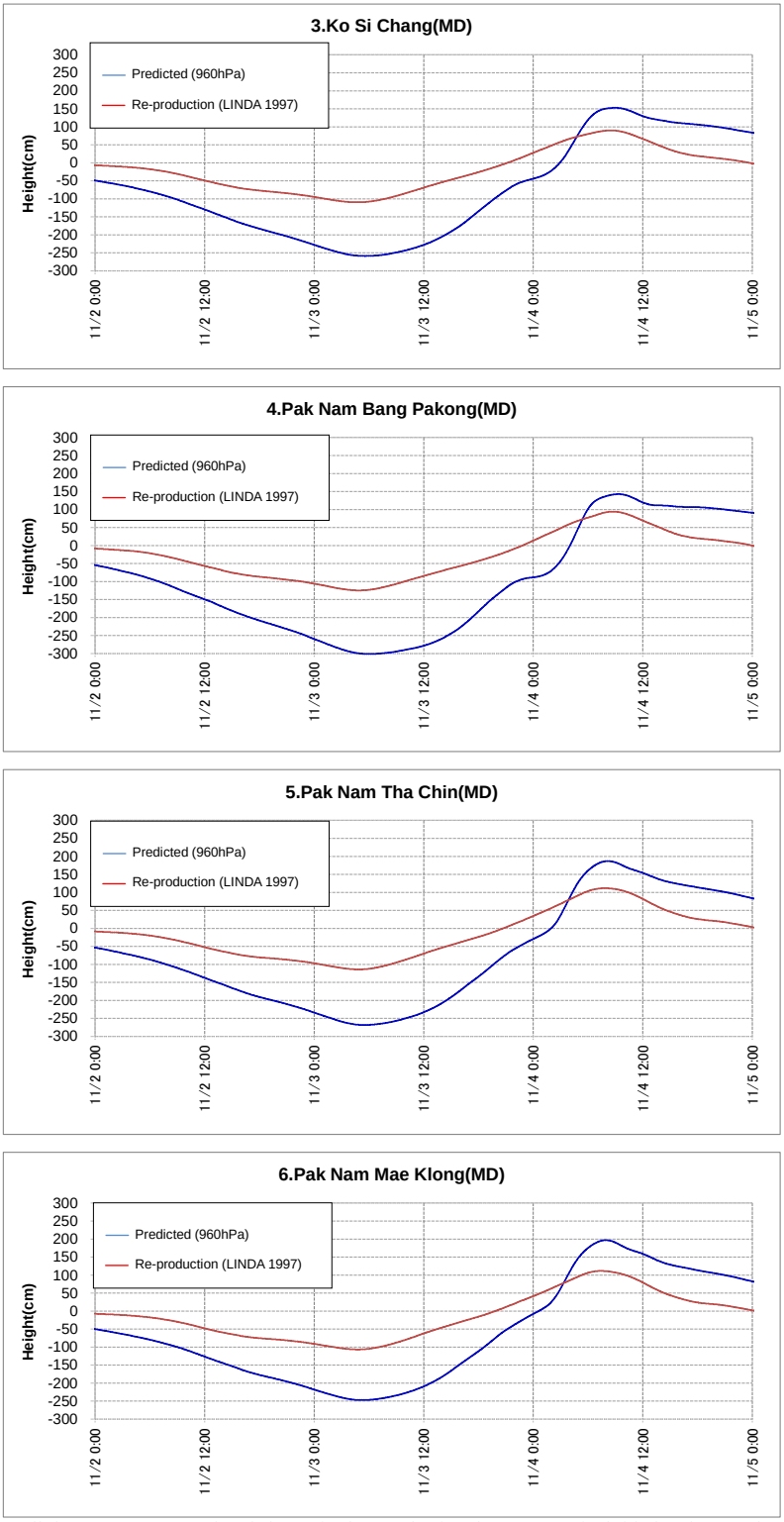


Figure S7.1.1 Track of Typhoon for Simulation (Modified Track of Typhoon Linda)

S7.2 Atmospheric pressure in center of typhoon

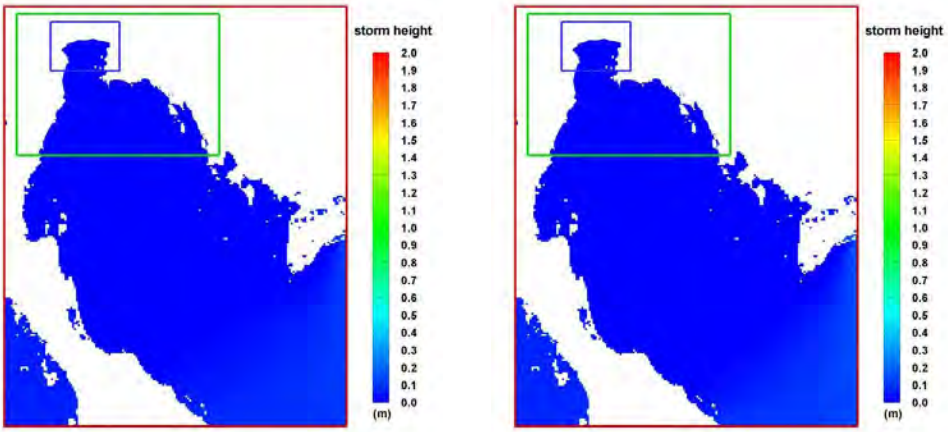
It was assumed that a typhoon with minimum atmospheric pressure was at 960hPa (referring to Typhoon Linda) hit the estuary of Chao Phraya River at the time of the high astronomical tide.

Figure S7.2.1 to Figure S7.2.9 show the comparison of the simulation result with the observed data at the tidal stations close to the estuary of Chao Phraya River. The tide level obtained from the simulation is higher than the result with Typhoon Linda (see Figure S6.1.2) by approximately 50 cm to 100 cm.



Note: All data were compared and shown in the graph after the astronomical tide level was subtracted.

Figure S7.2.1 Result of Time-Series Sea Level



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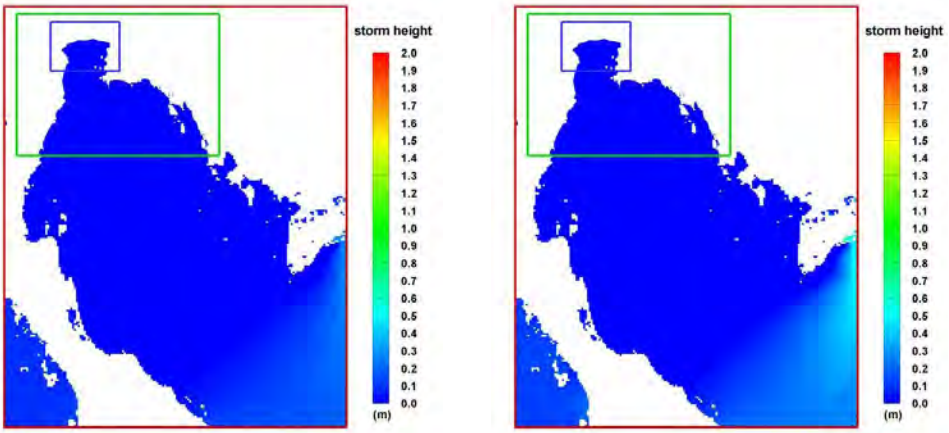

1997/11/2 3:00　　1997/11/2 9:00

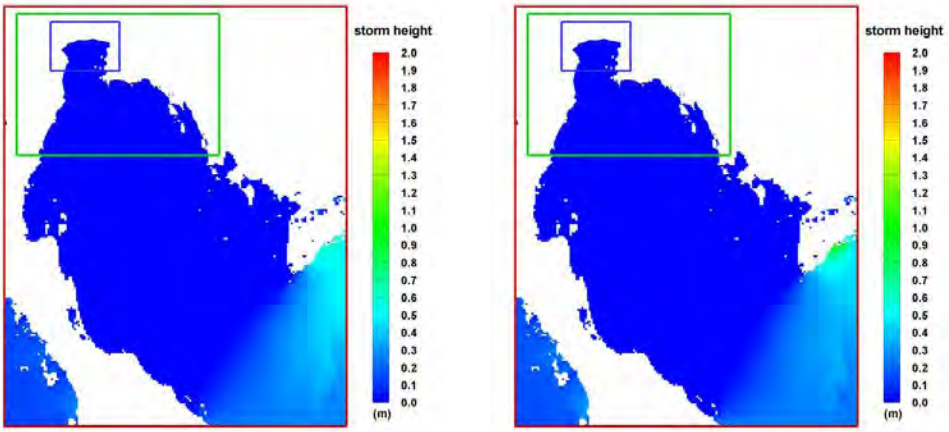

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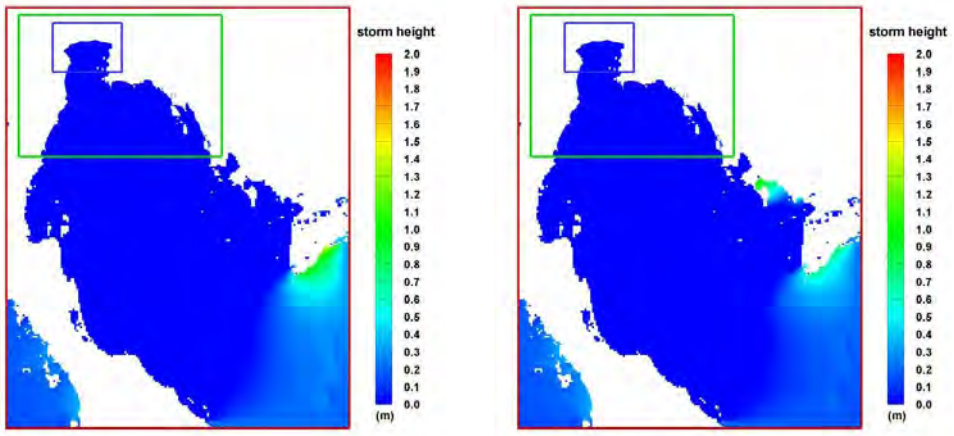
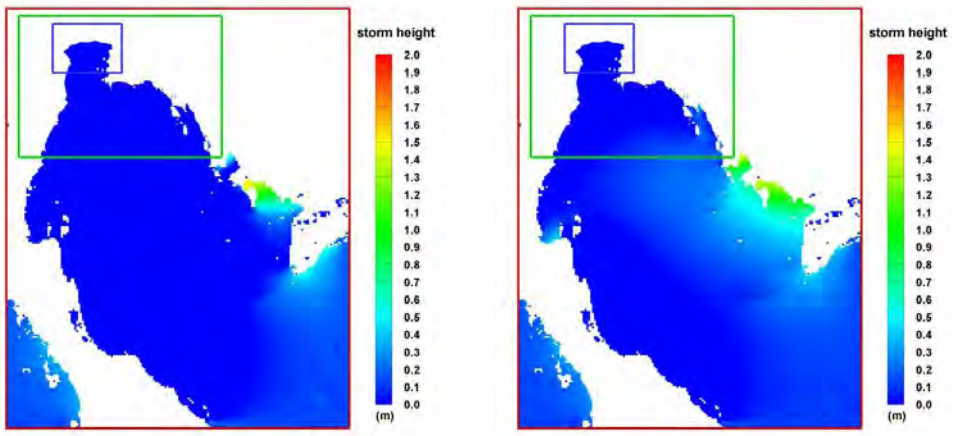
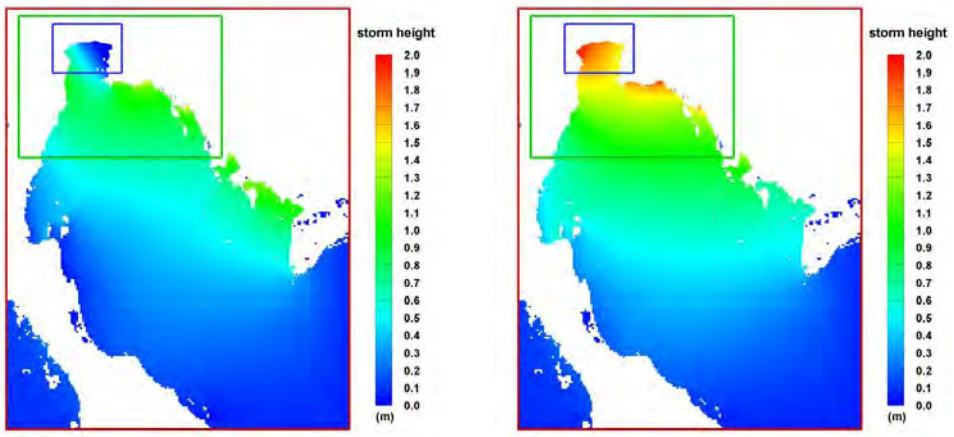
Figure S7.2.2　　Sea Level Rise in Simulation (1/3)



1997/11/3 3:00　　1997/11/3 9:00

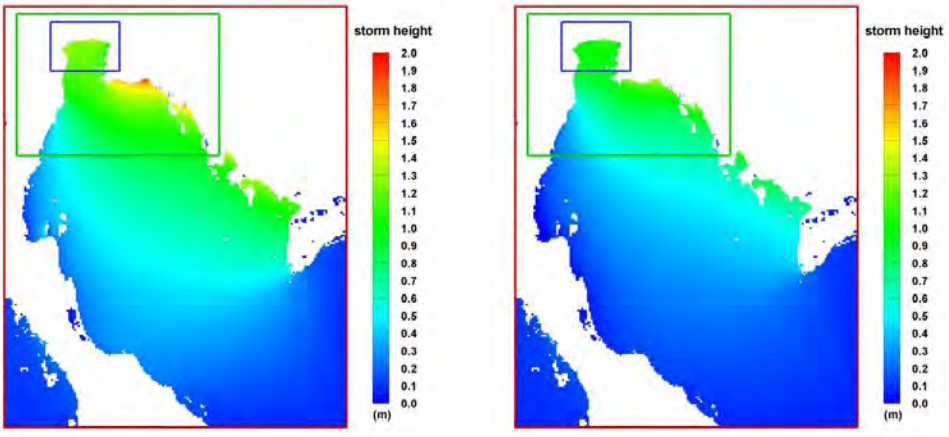


1997/11/3 15:00　　1997/11/3 21:00



1997/11/4 3:00　　1997/11/4 9:00

Figure S7.2.3　　Sea Level Rise in Simulation (2/3)



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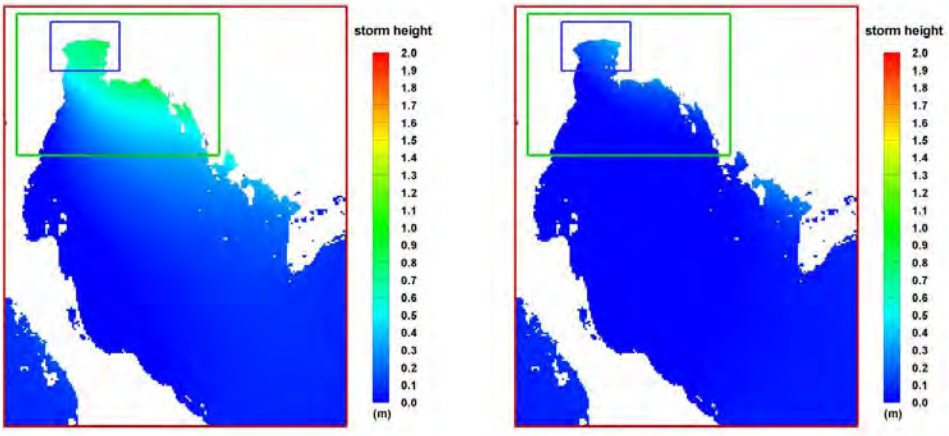

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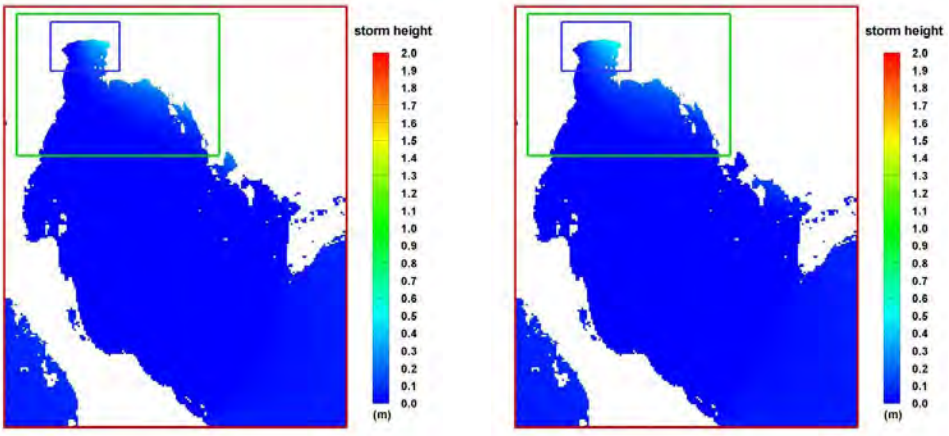

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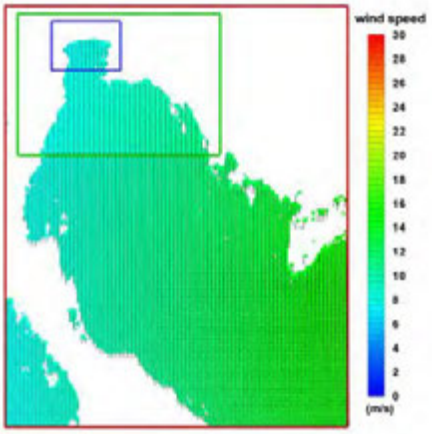
Figure S7.2.4　　Sea Level Rise in Simulation (3/3)



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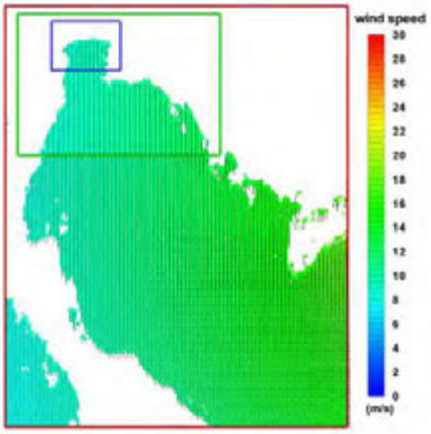

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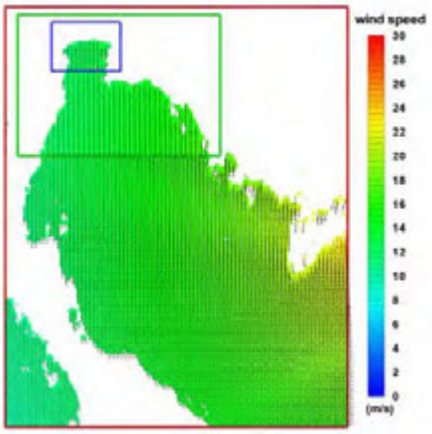

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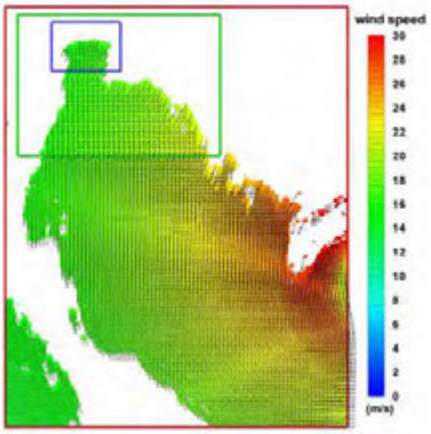

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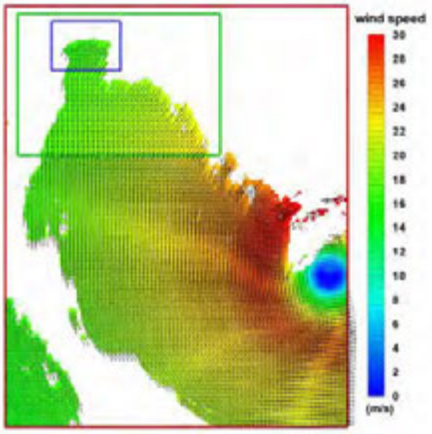

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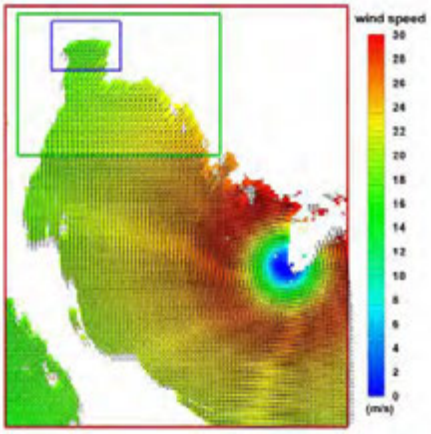

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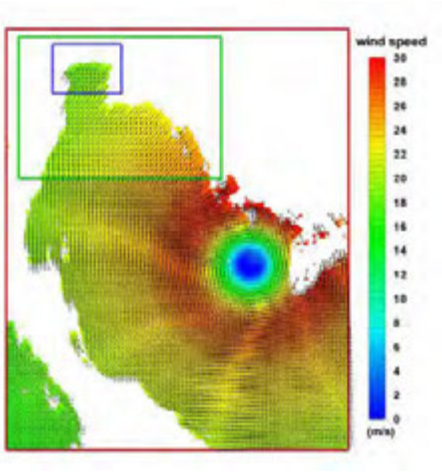
Figure S7.2.5 Wind Speed in Simulation (1/3)



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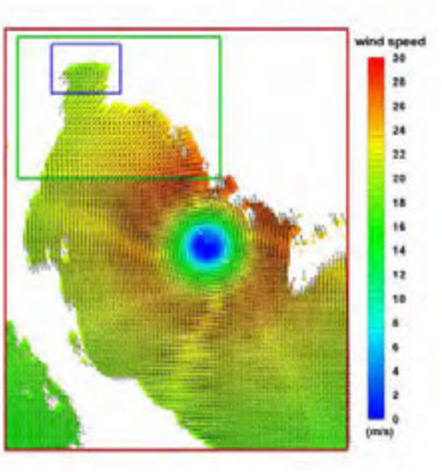

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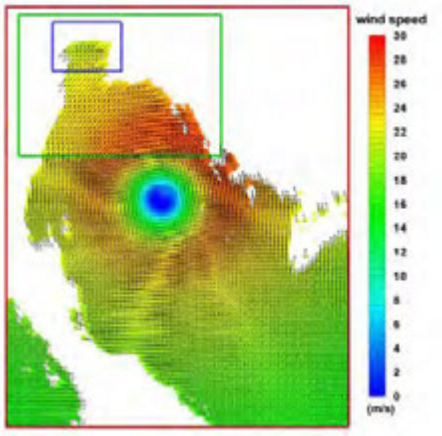

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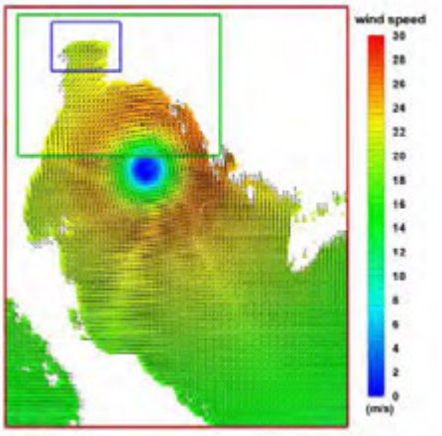

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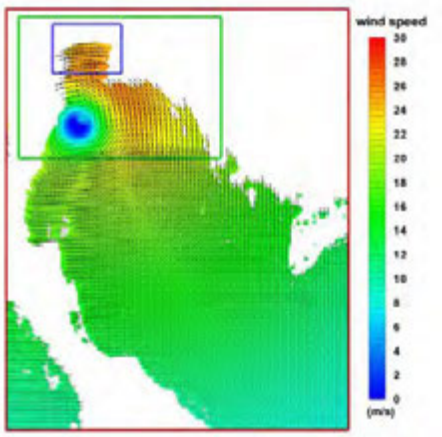

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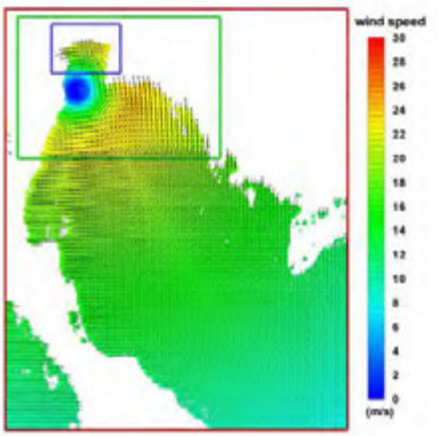

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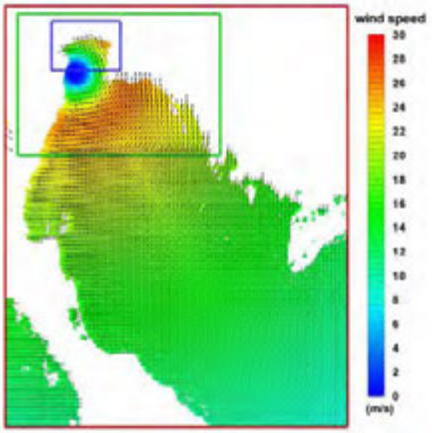
Figure S7.2.6 Wind Speed in Simulation (2/3)



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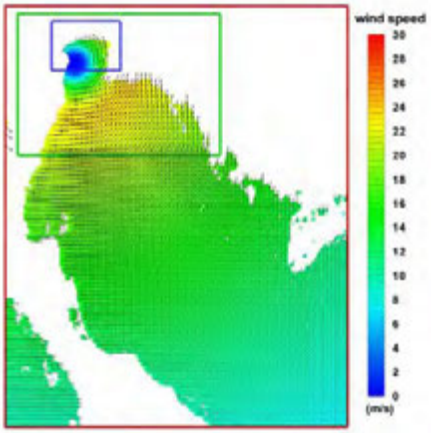

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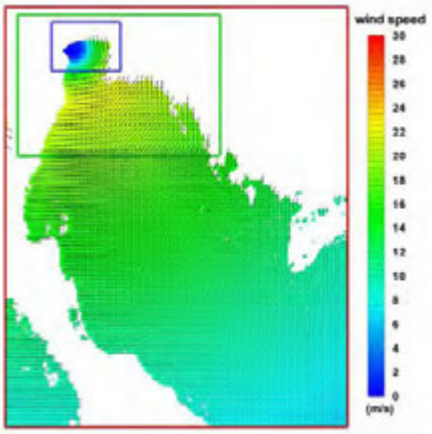

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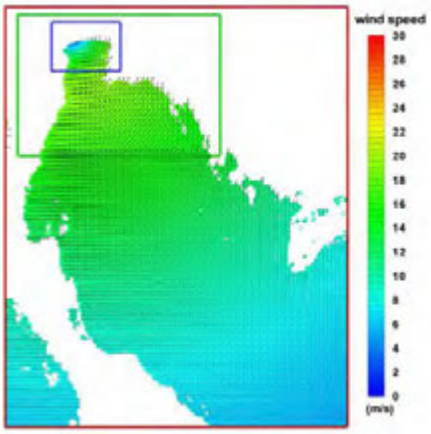

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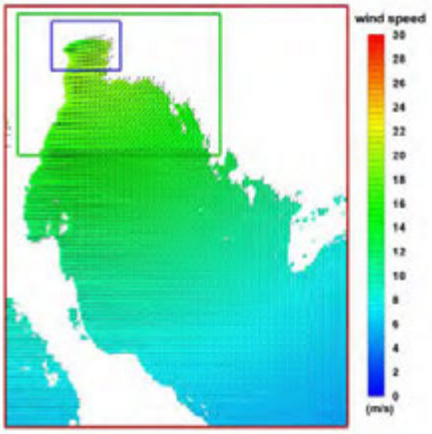

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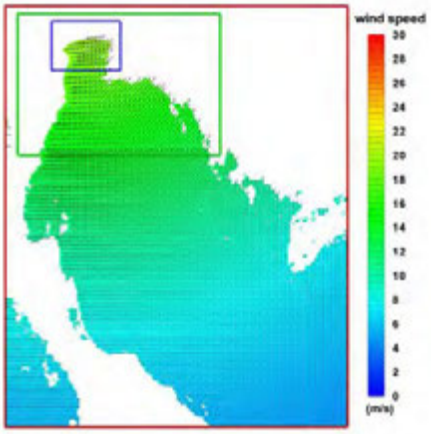

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Figure S7.2.7 Wind Speed in Simulation (3/3)

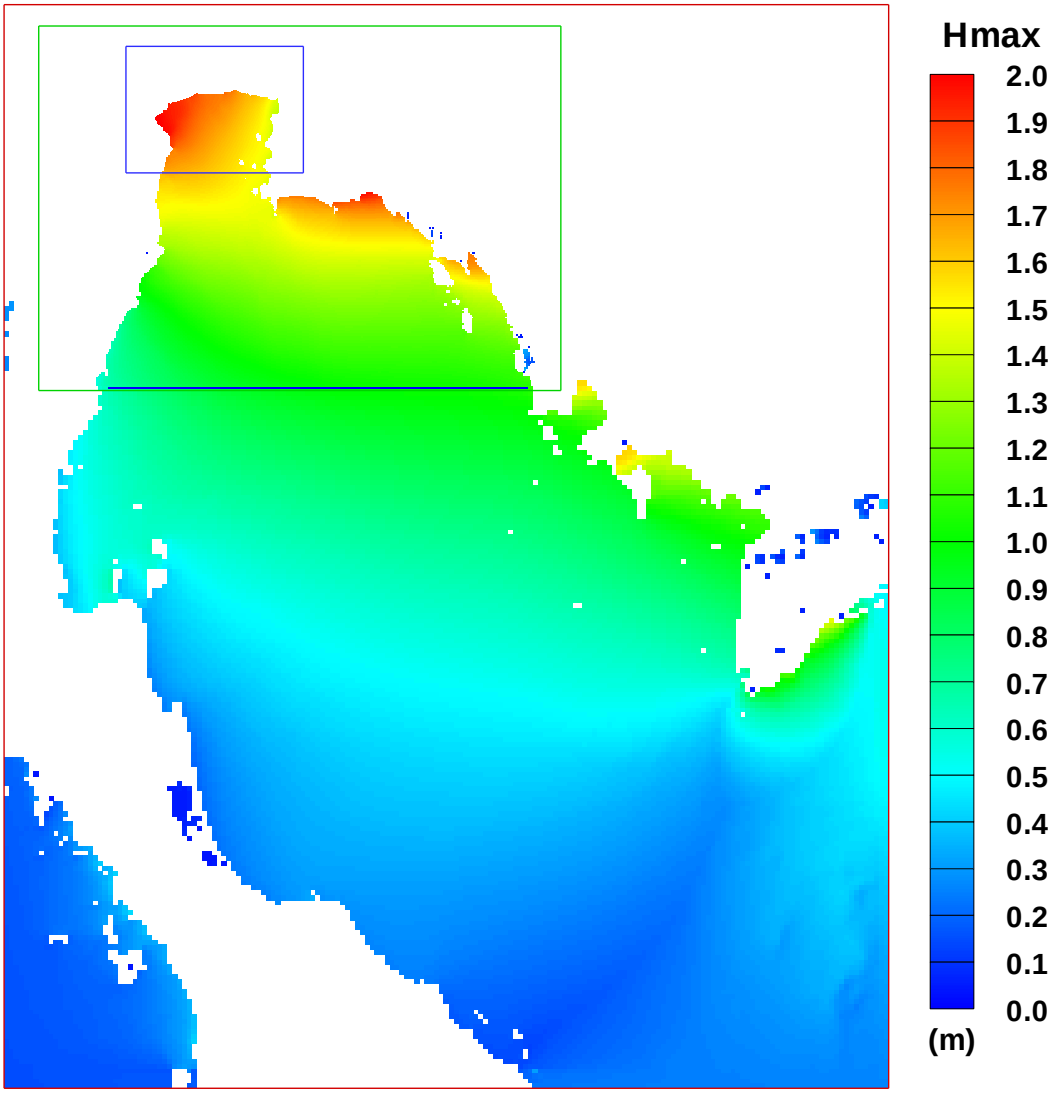


Figure S7.2.8 Maximum Sea Level Rise in Simulation

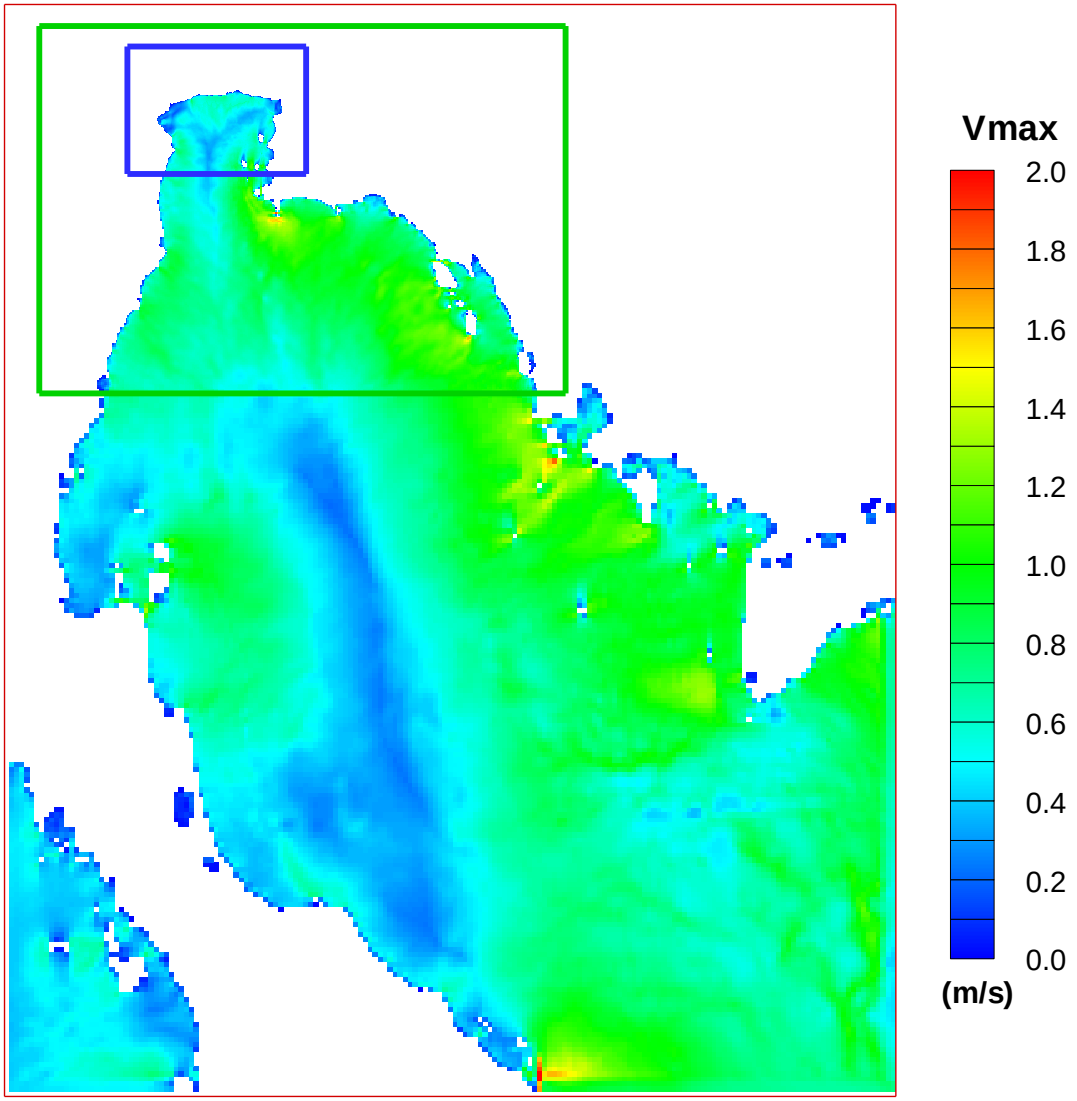


Figure S7.2.9 Maximum Flow Velocity in Simulation

Following the simulation result, the effect of the storm surge to the flood in Chao Phraya River Basin was analyzed. In this study, the following conditions were set:

- The storm surge with the highest sea water rise occurred on October 30 at the timing of the highest river water level;
- The sea water rise is at 2.0m at peak and lasted for 24 hours;
- Case 10 with the dike elevation around the economic zone, along Chao Phraya River and Pasak River, Ayutthaya Bypass and outer ring road diversion channel was selected for the examination of the study.

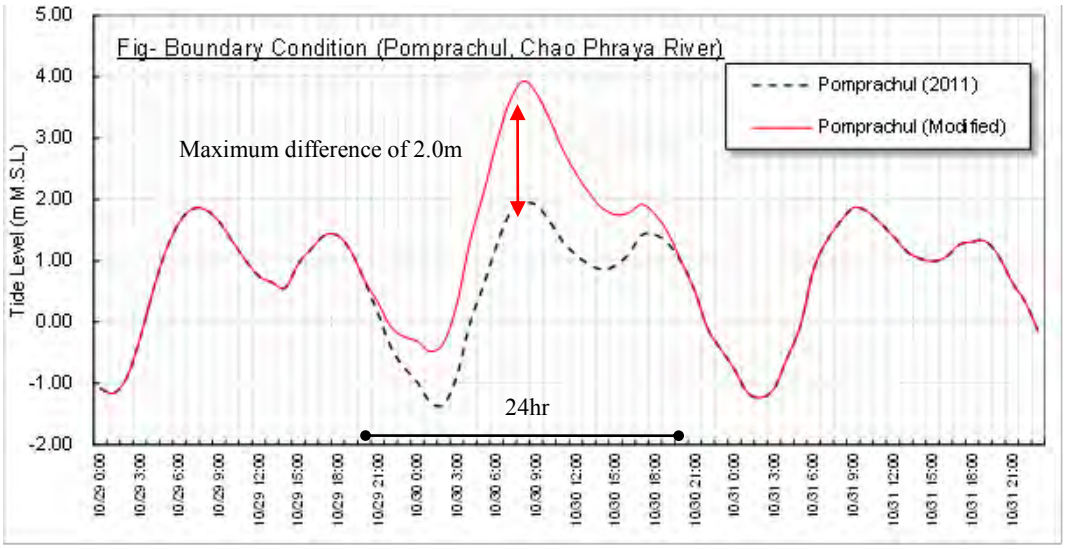
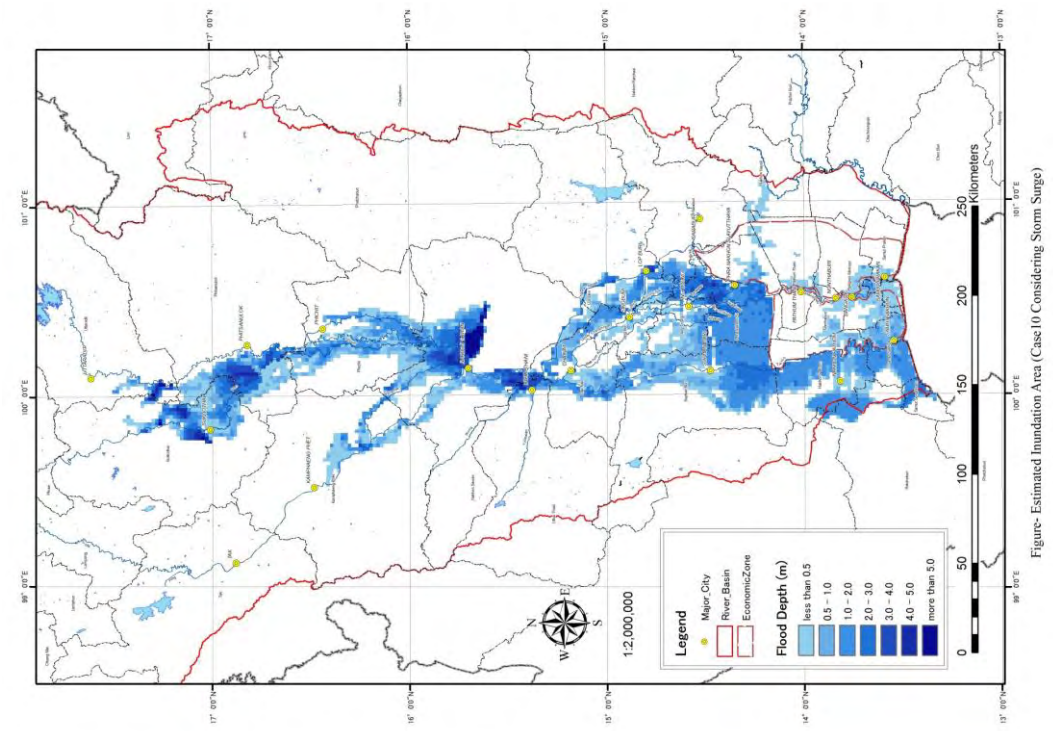
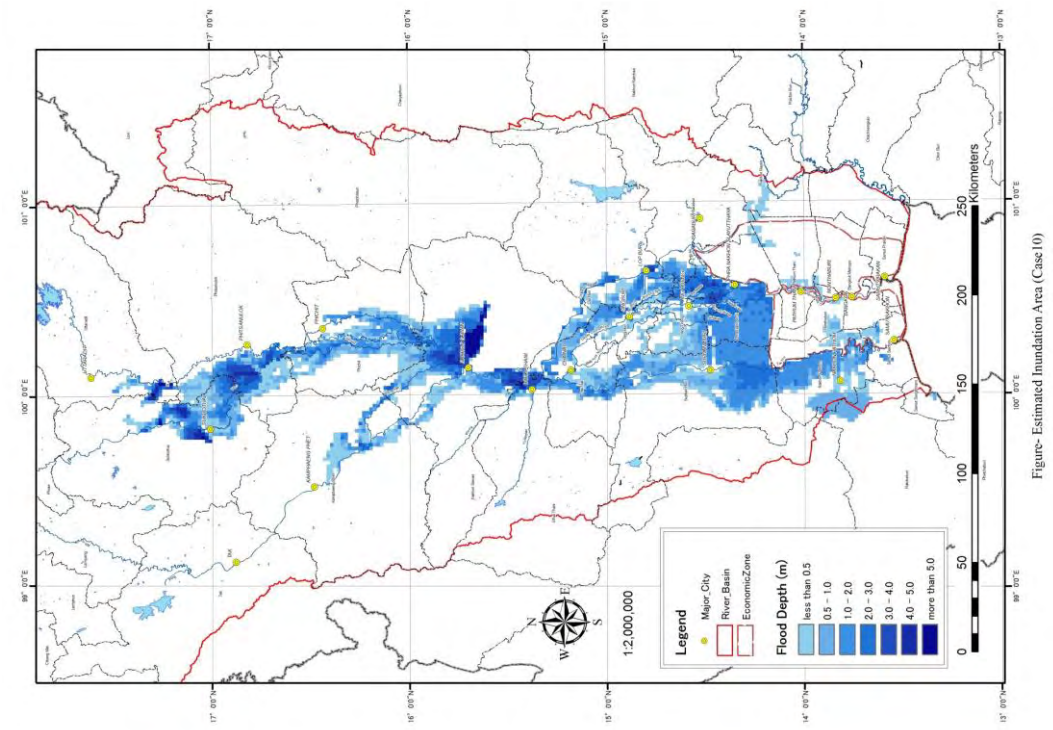


Figure S7.2.10 Application of Sea Level at Estuary of Chao Phraya River

Estimated inundation area is shown in Figure S7.2.11. It shows that the effect of the storm surge is not negligible to the flood in Chao Phraya River Basin. Approximately 600 MCM water volumes would overflow to the flood plain due to storm surge. In case of the huge storm surge, countermeasures including road rising along the coastline, river improvement works, construction of tide wall, etc., shall be examined.



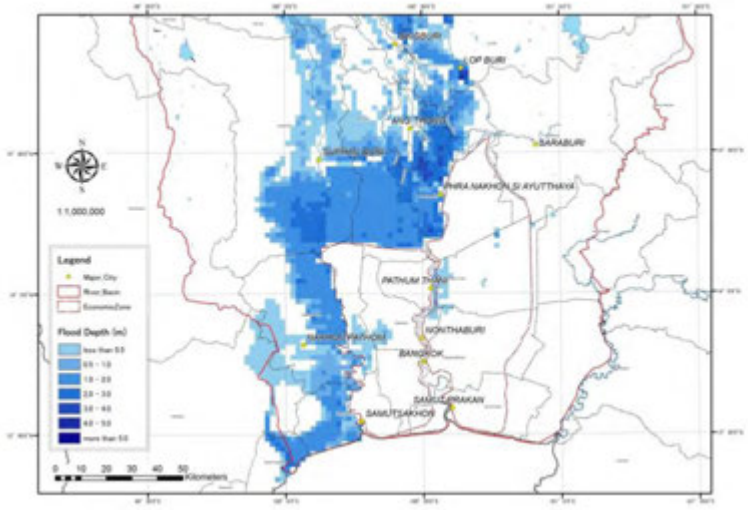
Case10 With Storm Surge (Elevation of Sea Level by 2m)



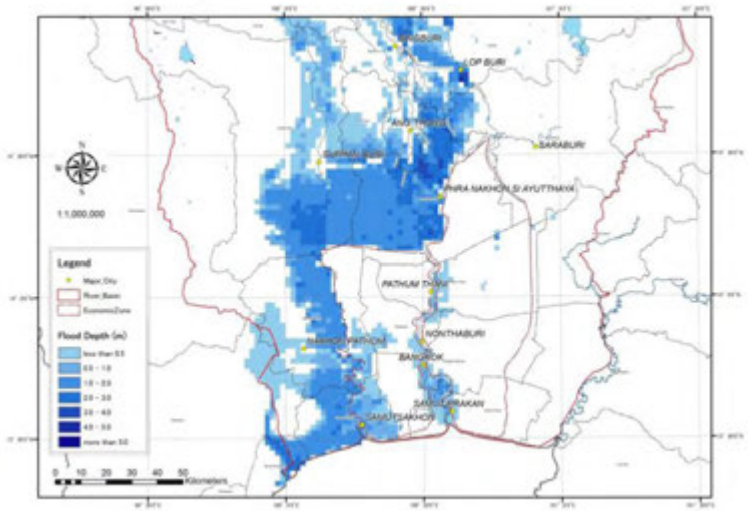
Case10 Without Storm Surge

Figure S7.2.11 Estimated Inundation Area in Chao Phraya River Basin

30 October 2011



31 October 2011



1 November 2011

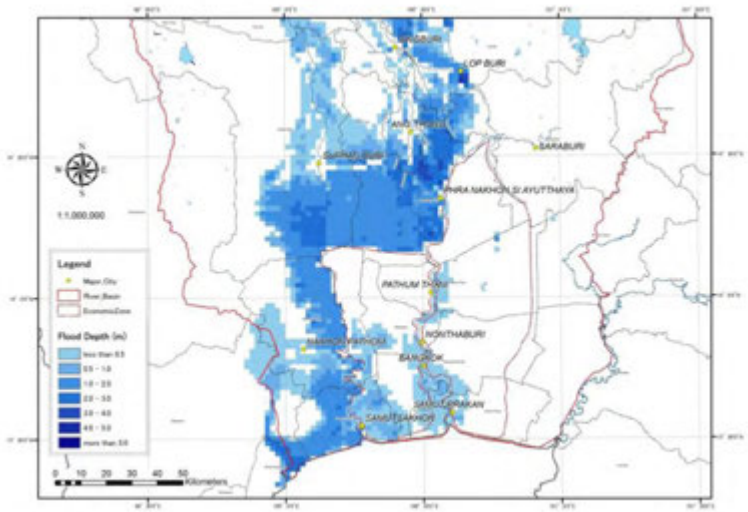


Figure S7.2.12 Estimated Inundation Area in Chao Phraya River Basin

CHAPTER S8 OBJECTIVE OF FUTURE ANALYSIS

S8.1 Compilation of typhoon data in 1960's and 1970's

The typhoon data in the 1960's and the 1970's will be obtained from the "Digital Typhoon" Home Page (http://agora.ex.nii.ac.jp/digital-typhoon/). Presently, the atmospheric pressure at the center of the typhoons is missing. Especially, the typhoon data with the comparatively low pressure at the center of the typhoon should be mainly focused.

S8.2 Track of modified typhoon in simulation

The track of the modified typhoon (See S7.1) should be studied to check if there is any other track which affects the flood in Chao Phraya River Basin.

Sector T: Examination of Observed Data by RID

PROJECT FOR THE COMPREHENSIVE FLOOD MANAGEMENT PLAN FOR THE CHAO PHRAYA RIVER BASIN

FINAL REPORT
VOLUME 3: SUPPORTING REPORT

SECTOR T: TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER T1 DISCHARGE OBSERVATION AT RID HYDROLOGICAL STATIONS

Hydro 5 was contacted to gather information regarding discharge observation at RID hydrological stations including the following 10 stations, C2, C13 D/S, C3, C7A, C35, C36, C37, S5, S26, C29A.

T1.1 Method of Discharge Observation and Discharge Calculation

There are three survey methods, River Surveyor (ADCP), Current Meter, H-ADCP which are being used at each station as summarized in Table T1.1.1.

Table T1.1.1 List of Discharge Observation Method

Sta.	Instrument	Remarks
C2	River Surveyor M9, Propeller Current Meter	-
C13 D/S	River Surveyor M9, Propeller Current Meter	On December 13, 2012, the field survey conducted by River Surveyor M9 was observed.
C3	River Surveyor M9, Propeller Current Meter	-
C7A	River Surveyor M9, Propeller Current Meter	-
C35	River Surveyor M9, Propeller Current Meter	-
C36	River Surveyor M9, Propeller Current Meter	-
C37	River Surveyor M9, Propeller Current Meter	-
S5	River Surveyor M9, Propeller Current Meter	-
S26	River Surveyor M9, Propeller Current Meter	-
C29A	H-ADCP (Side Looking)	Due to the tidal effect, this station adapts the H-ADCP (Side Looking). A fixed type "Side Looking: WinH-ADCP" measures water level and velocity every one hour.

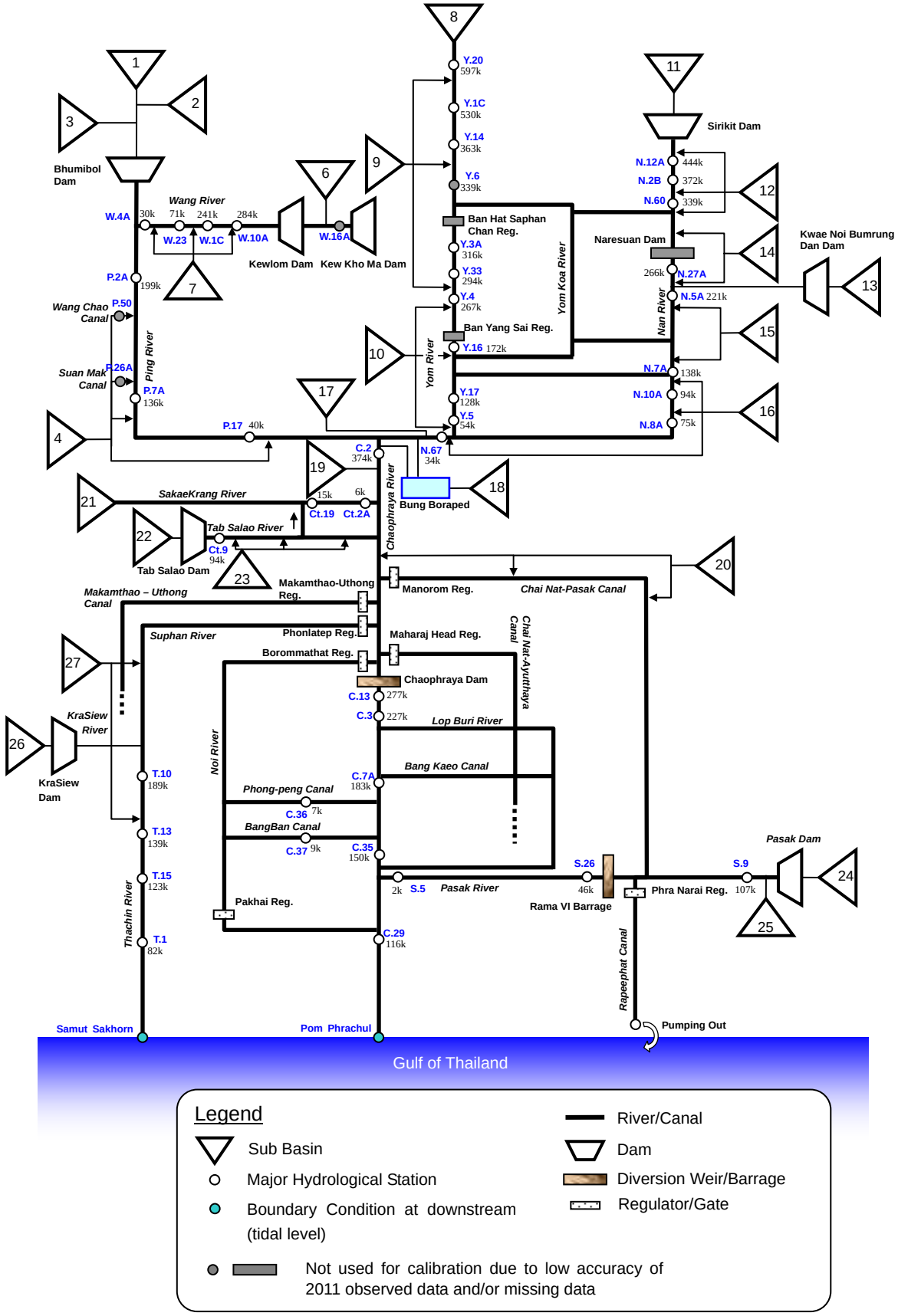


Figure T1.1.1 Hydrological Stations Reflected in Modeling

Table T1.1.2 Survey Method: River Surveyor M9 (ADCP)

River Surveyor M9 (Sontek)	
Survey Method	
• River Surveyor M9 is mounted on a boat which is operated by two staff. Wakitoki is used for the communication between staff on the boat and land. The land staff uses his laptop computer for checking the real-time survey data transmitted from River Surveyor M9 to the laptop computer. • The cross sectional survey is conducted along rope stretched across the river channel. At the time of site visit on December 13th, 2012, the velocity was slow enough to conduct the manual survey (Manual Survey: staff pulls a rope to navigate the boat manually. No motor engine was used.). Motor engine is used only when the velocity is too fast that manual navigation cannot secure the straight path along the rope. According to the RID officer, the manual navigation can collect stable and accurate survey results than the motor engine survey. • The first and end points of measurement are taken about 5 m from right and left banks respectively. • A roundtrip survey (measurement taken from right to left, and then left to right) is considered as one set. In total, surveyors take 4 sets per field survey. • Among the 4 sets of measurements, if difference is more than 5 percent, the survey team discuss about the validity of the measurements. If the measurement is deemed to be abnormal, additional surveys will be conducted. • The discharge will be calculated by averaging all measurements (4 sets data). • The cross sectional survey at C13 is taken roughly 1 km downstream of the Chao Phraya Dam. The channel width is approximately 150 m which takes about 10 minutes to conduct one set of survey (roundtrip). • RID officer commented that they would like to conduct the survey by River Surveyor at every station under jurisdiction of Hydro5 Center, however it is difficult due to the availability of the equipment (Hydro 5 owns only one machine at the time of field survey in 2012).	
Equipment	
	
River Surveyor M9	Mount On Plat Form for River Surveyor

	
Data Checking on Computer	Cross Section Survey by River Surveyor
Discharge Calculation	
• River Surveyor measures water depth and velocity, and calculate area to determine discharge. • No calculation at office is necessary.	

Table T1.1.3 Specifications of SonTek/YSI River Surveyor M9

Item	M9
Velocity Measurement	
Profiling Range (Distance)	0.06 to 40m
Profiling Range (Velocity)	±20 m/s
Accuracy	±0.25% of measured velocity
Resolution	0.001 m/s
Number of Cells	Up to 128
Cell Size	0.02 to 4m
Transducer Configuration	Nine (9) Transducers
	Dual 4-beam 3.0 MHz/1.0 MHz
	Janus at 25° Slant Angle
	0.5 MHz Vertical Beam
Depth Measurement	
Range	0.20 to 80m
Accuracy	1%
Resolution	0.001 m
Discharge Measurement	
Range with Bottom-Track	0.3 to 40m
Range with RTK GPS	0.3 to 80 m
Computations	Internal

Source: http://www.sontek.com/riversurveyor-s5-m9.php

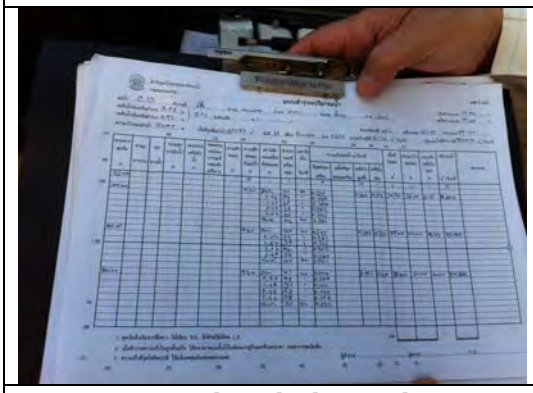
Table T1.1.4 Survey Method: Propeller Current Meter

Propeller Current Meter

Survey Method

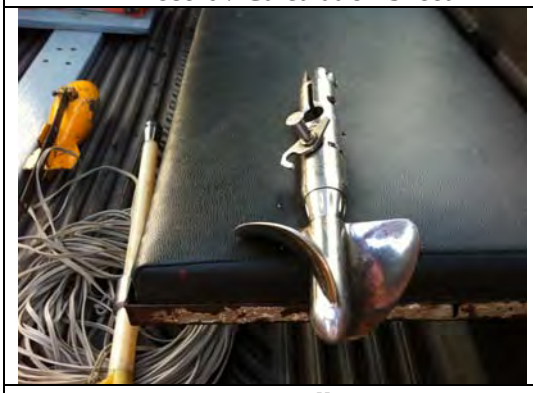
- Propeller Current Meter is attached to a measuring rod with counter. The counter is used to count the current meter.
- Propeller Current Meter is used only during the dry season (low velocity season).
- The area of discharge measurement is divided into 10 sub-sections: T/10（where T is a channel width). The measurement of velocity is taken at 6 locations along the vertical line including at water surface, 0.2d, 0.4d, 0.6d, 0.8d, and channel bottom (where d is water depth at each survey location). These 6 measurements are then averaged and used for discharge calculation at each sub-section.
- A counter is used to count Propeller Current Meter (40 seconds per measurement). Then velocity is calculated by using a conversion table which converts the counted number into velocity (m/s). The conversion table is unique for each Current Meter, therefore, a calibration of the Current Meter and the conversion table is conducted once a year at an Institute.
- Measurement is taken only one way per survey from left bank to right bank. (River Surveyor conducts a roundtrip measurement whereas Current Meter conducts only one way.)

Equipment



Record / Calculation Sheet

Counter for Current Meter



Current Meter: Propeller Current Meter

Measuring Rod (to measure water depth)

Discharge Calculation

- Discharge is simply velocity times cross-sectional area: Q=AV.

T1.2 Measurement Frequency

The frequency of measurement is determined according to following two conditions:

(1) Whenever the change in water level is more than 30 to 50 cm.

(2) When there is no change in water level, survey will be conducted once or twice a week.

T1.3 H-Q Curve Preparation

(1) Official H-Q curve is prepared at the end of RID Water Year (The Water Year: starts April and end March next year). As of December 13, 2012, officer was working on finalizing the official H-Q curve of 2011.

(2) Calibration of the official H-Q curve is conducted whenever new data is available after the field survey. The new data is plotted in the H-Q curve, and the curve is adjusted as required.

(3) To determine the discharge which does not fall within the range of the existing H-Q curve, RID officer will first extend the existing curve by following the trend, and then read the discharge based on the modified H-Q curve.

(4) Hydro 5 Centre is responsible for drawing up, finalizing, and adjusting H-Q curves at all ten (10) stations (C2, C13 D/S, C3, C7A, C35, C36, C37, S5, S26, C29A), and the submission of the official H-Q curved to RID HQ (Bangkok・Samsen).

H-Q Curve Preparation

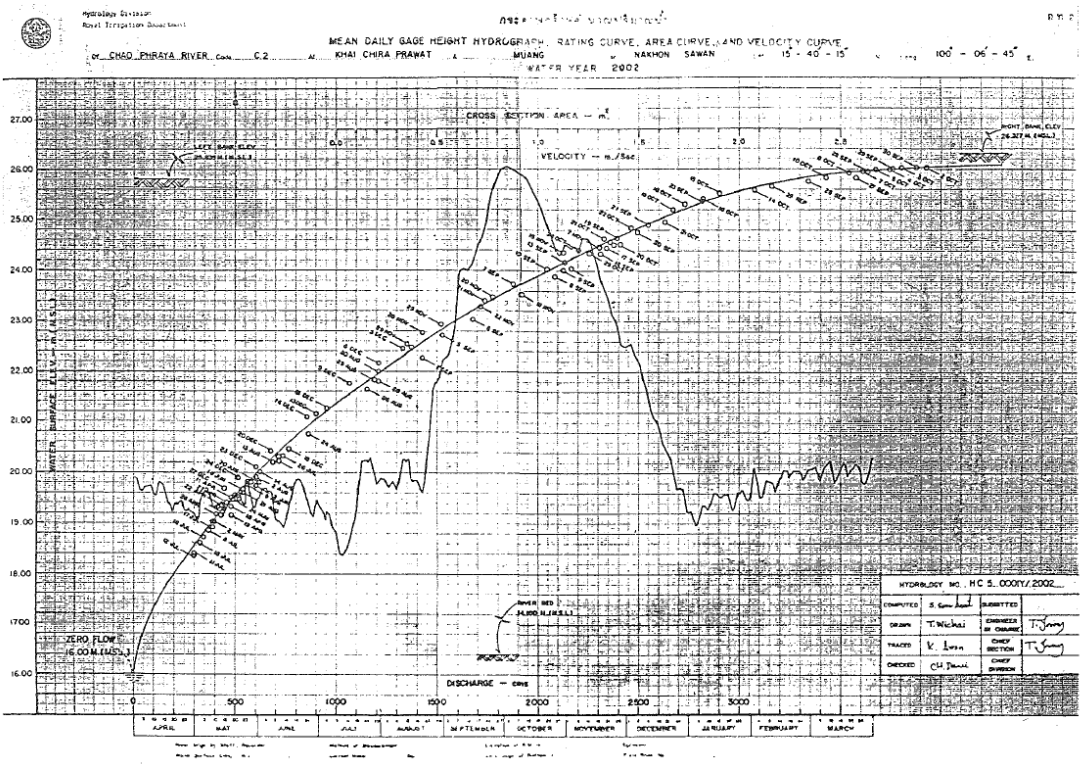


Figure T1.3.1 H-Q Curve at C.2 Station (2002)

T1.4 Water Level, Discharge and H-Q Survey in 2011

In this section, two data sets are compared, 1) Recorded Data: official recorded data of discharge and water level produced by RID Hydrology Division, and 2) H-Q Survey: Water level (H) and discharge (Q) survey conducted by Hydro 5 at each station several times per year.

T1.4.1 C2 (Nakhon Sawan）

H-Q survey were conducted 20 times at C2（Nakhon Sawan） from August to November 2011 as shown in Table T1.4.1. The comparison of water level measurement between Recorded Data and H-Q Survey data is shown in Figure T1.4.1, while velocity measurement by H-Q Survey is shown in Figure T1.4.2. Figure T1.4.3 shows the cross-section at C2 where H-Q Survey is taken.

Table T1.4.1 H-Q Survey between August to November 2011 at C2（Nakhon Sawan）

Date	Level (m MSL)	Survey Time	Water Surface Width (m)	Area (m2)	Velocity (m/s)	Discharge (m3/s)	H-Q Survey Method
2011/8/3	22.51	10:30-11:45	278.00	1,780.20	0.883	1,573	Propeller Current Meter
2011/8/5	23.05	11:07-12:30	292.00	1,937.40	0.924	1,790	Propeller Current Meter
2011/8/6	23.22	10:30-12:10	292.00	1,988.06	0.963	1,914	Propeller Current Meter
2011/8/6	23.23	14:33-14:40	299.33	2,007.60	0.905	1,816	River Surveyor M9
2011/8/8	23.38	10:10-11:35	293.00	2,058.25	0.946	1,948	Propeller Current Meter
2011/8/15	23.62	10:20-11:45	295.00	2,111.30	0.987	2,084	Propeller Current Meter
2011/8/17	23.73	11:27-11:45	289.87	2,122.30	0.933	1,980	River Surveyor M9
2011/8/22	24.20	10:15-11:35	298.00	2,256.80	0.983	2,218	Propeller Current Meter
2011/9/1	25.26	10:30-12:00	300.00	2,558.00	1.144	2,927	Propeller Current Meter
2011/9/6	25.65	10:10-12:00	309.00	2,706.90	1.205	3,262	Propeller Current Meter
2011/9/13	26.05	10:00-12:10	309.00	2,783.35	1.389	3,867	Propeller Current Meter
2011/9/14	26.19	18:12-18:30	292.91	2,586.80	1.270	3,261	River Surveyor M9
2011/9/15	26.26	11:06-11:18	308.52	2,738.90	1.296	3,548	River Surveyor M9
2011/9/16	26.32	09:07-09:37	315.76	2,660.90	1.353	3,599	River Surveyor M9
2011/9/18	26.24	14:55-15:26	325.25	2,740.00	1.355	3,714	River Surveyor M9
2011/9/25	26.63	10:48-11:03	316.71	2,898.00	1.475	4,273	River Surveyor M9
2011/11/3	25.69	10:30-12:30	307.00	2,628.00	1.219	3,203	Propeller Current Meter
2011/11/7	25.27	10:30-11:50	301.00	2,502.70	1.095	2,739	Propeller Current Meter
2011/11/22	23.53	10:00-11:30	296.00	2,206.20	0.828	1,826	Propeller Current Meter
2011/11/29	21.83	12:00-13:40	270.00	1,655.25	0.743	1,230	Propeller Current Meter

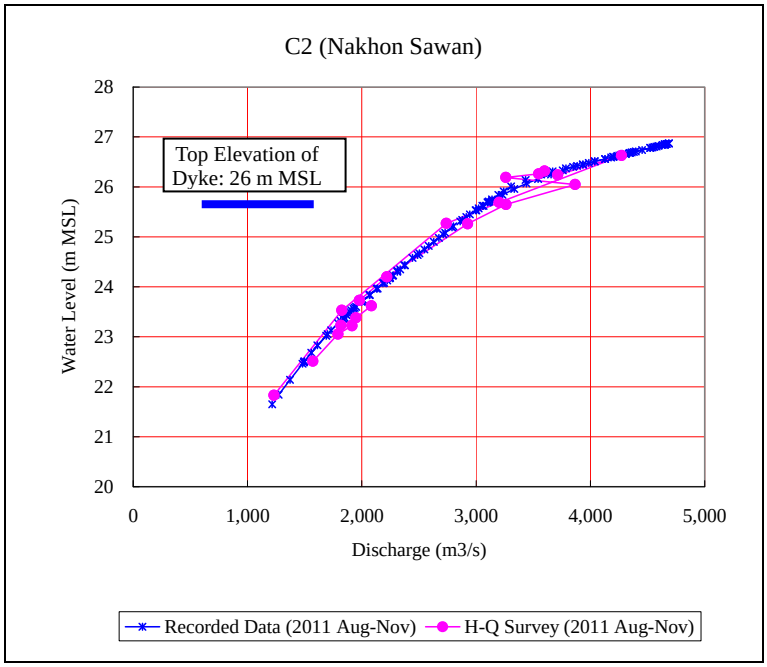


Figure T1.4.1 Recorded Data and H-Q Survey at C2 (Nakhon Sawan)

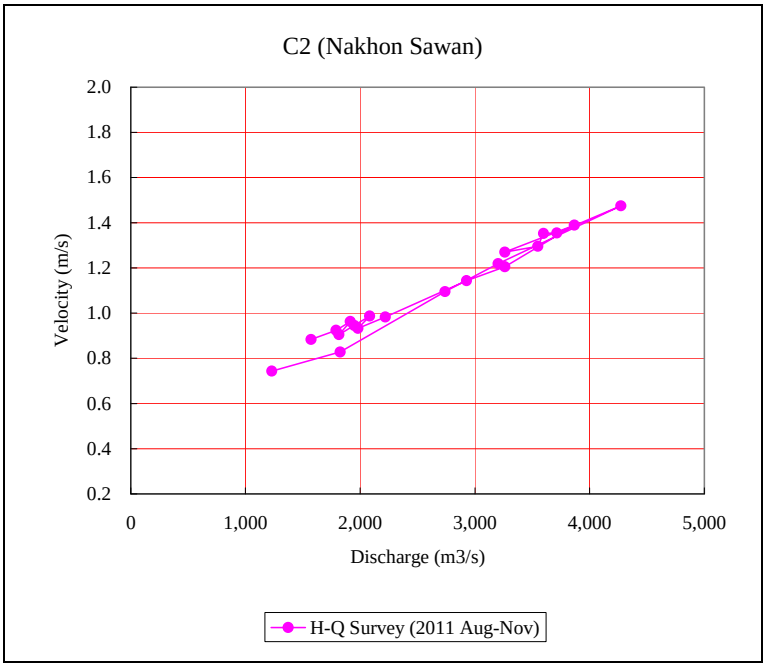


Figure T1.4.2 Velocity Measurement by H-Q Survey at C2 (Nakhon Sawan)

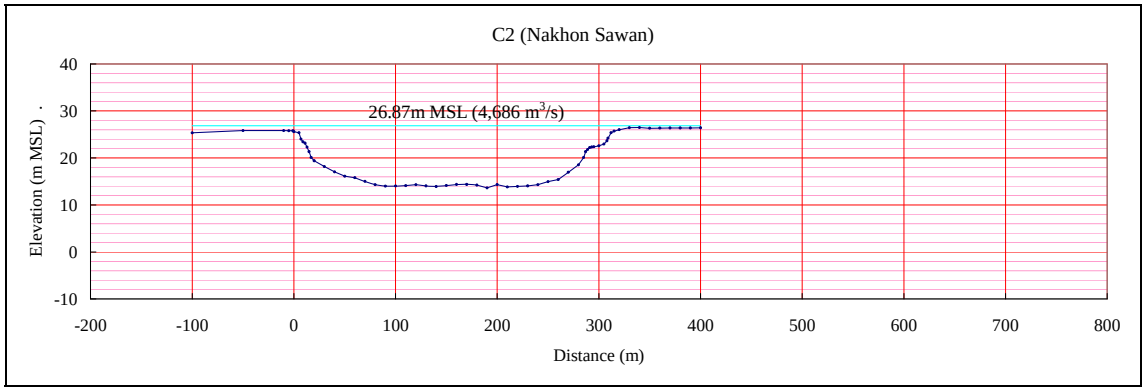


Figure T1.4.3 Cross Section of H-Q Survey at C2 (Nakhon Sawan)

(1) According to Figure T1.4.1, the Recorded Data in 2011 is reasonable as it is based on H-Q Survey results.

(2) The peak discharge in 2011 at C2 was 4,686 m^3/s. It must be noted that this peak discharge is considered to be much smaller than the actual discharge occurred during the 2011 Flood. According to the RID record, the top elevation of channel bank (the primary dyke) is approximately 26 m MSL. During the 2011 Flood, the maximum water level was 26.87 m MSL, which indicates that the water overflowed banks in adjacent areas. However, the maximum width of water surface from H-Q Survey was 325 m, roughly equal to the water surface width at bankfull flow. The peak discharge of 4,686 m^3/s was calculated only based on the water volume within the channel (which means this record is not taking into account the volume of overflowed water). Therefore, it is concluded that the actual peak discharge could be much larger than the recorded peak discharge of 4,686 m^3/s.

T1.4.2 C13 D/S (Downstream of Chao Phraya Dam)

H-Q survey were conducted 16 times at C13 D/S（Downstream of Chao Phraya Dam） from August to November 2011 as shown in Table T1.4.2. The comparison of water level measurement between Recorded Data and H-Q Survey data is shown in Figure T1.4.4 while velocity measurement by H-Q Survey is shown in Figure T1.4.5. Figure T1.4.6 shows the cross-section at C13 D/S where H-Q Survey is taken.

Table T1.4.2 H-Q Survey between August to November 2011 at C13 D/S (Downstream of the Chao Phraya Dam)

Date	Level (m MSL)	Survey Time	Water Surface Width (m)	Area (m2)	Velocity (m/s)	Discharge (m3/s)	H-Q Survey Method
2011/8/2	12.45	14:57-15:20	223.16	1,793.80	0.698	1,251	River Surveyor M9
2011/8/3	12.46	10:08-10:25	217.84	1,786.10	0.690	1,232	River Surveyor M9
2011/8/9	12.57	09:05-10:30	221.00	1,762.40	0.726	1,279	Propeller Current Meter
2011/8/16	13.14	13:00-14:30	228.00	1,894.50	0.838	1,588	Propeller Current Meter
2011/8/18	13.76	09:39:09:56	213.19	1,943.20	0.839	1,630	River Surveyor M9
2011/8/22	14.13	15:47:16:04	221.56	1,987.40	0.885	1,789	River Surveyor M9
2011/8/25	13.98	09:30-10:30	229.00	2,058.70	0.880	1,813	Propeller Current Meter
2011/9/2	15.30	13:45-16:00	235.00	2,236.45	1.021	2,282	Propeller Current Meter
2011/9/12	16.71	09:45-11:35	262.00	2,799.30	1.080	3,022	Propeller Current Meter
2011/9/15	17.52	16:46-16:58	345.92	2,793.25	1.155	3,434	River Surveyor M9
2011/9/16	17.71	14:06-14:21	349.24	3,044.00	1.190	3,571	River Surveyor M9
2011/9/25	17.85	15:10-15:23	334.00	2,797.00	1.325	3,706	River Surveyor M9
2011/10/2	17.51	12:53-13:29	328.95	2,712.20	1.318	3,572	River Surveyor M9
2011/10/19	17.53	-	-	3,022.86	1.198	3,621	River Surveyor M9
2011/11/21	14.26	09:15-11:00	233.00	2,145.90	0.839	1,800	Propeller Current Meter
2011/11/30	11.27	09:00-10:30	191.00	1,532.70	0.589	903	Propeller Current Meter

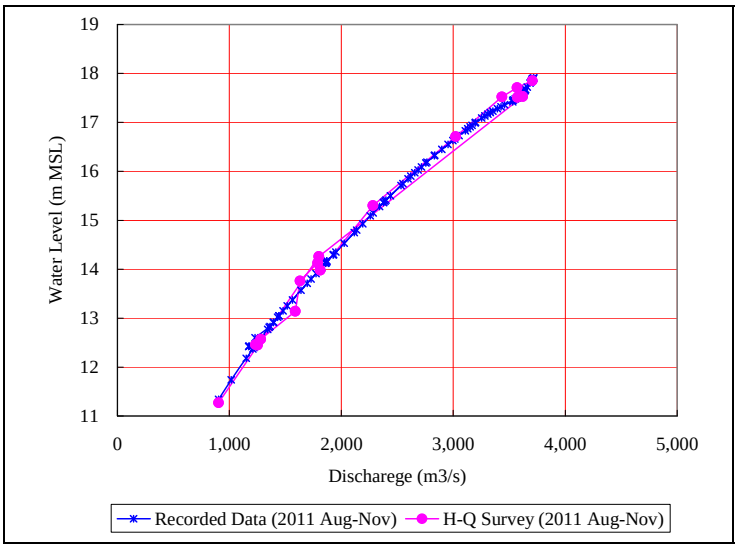


Figure T1.4.4 Recorded Data and H-Q Survey at C13 D/S (Downstream of Chao Phraya Dam)

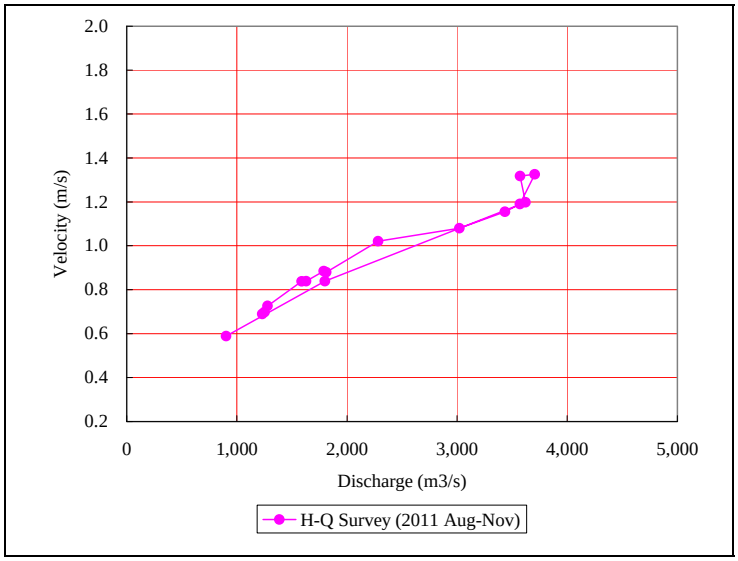


Figure T1.4.5 Velocity Measurement by H-Q Survey at C13 D/S (Downstream of Chao Phraya Dam)

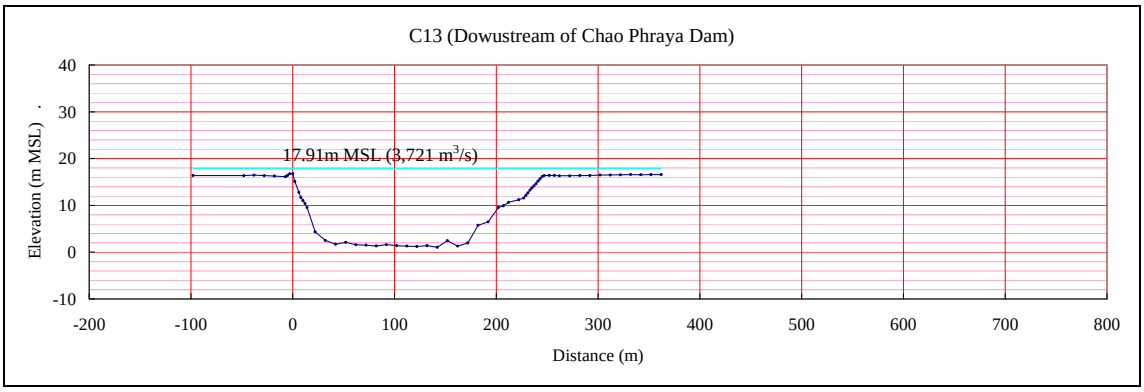


Figure T1.4.6 Cross Section of H-Q Survey at C13 (Downstream of Chao Phraya Dam)

(1) According to Figure T1.4.4, the Recorded Data in 2011 is reasonable as it is based on H-Q Survey results generated by ADCP and propeller current meter.

(2) The peak discharge in 2011 at C13 D/S was 3,721 m^3/s. It must be noted that the peak discharge is considered to be much smaller than the actual discharge occurred during the 2011 Flood. According to the RID record, the top elevation of channel bank (the primary dyke) is approximately 16.6 to 16.8 m MSL. During the 2011 Flood, the maximum water level was 17.91 m MSL, which indicates that the water overflowed banks in adjacent areas. However, the maximum width of water surface from H-Q survey was 349 m, roughly 100 m wider than the water surface width at bankfull flow. The peak discharge of 3,721 m^3/s was calculated based on the water volume within the channel and the extended section of about 100 m (which means this record is not taking into account the volume overflowed water except for the extended section). Therefore, it is concluded that the actual peak discharge could be much larger than the recorded peak discharge of 3,721 m^3/s.

T1.4.3 C3 (Sing Buri)

H-Q survey were conducted 14 times at C3（Sing Buri） from August to November 2011 as shown in Table T 1.4.3. The comparison of water level measurement between Recorded Data and H-Q Survey data is shown in Figure T1.4.7, while velocity measurement by H-Q Survey is shown in Figure T1.4.8. Figure T1.4.9 shows the cross-section at C3 where H-Q Survey is taken.

Table T 1.4.3 H-Q Survey between August to November 2011 at C3 (Sing Buri)

Date	Level (m MSL)	Survey Time	Water Surface Width (m)	Area (m2)	Velocity (m/s)	Discharge (m3/s)	H-Q Survey Method
2011/8/2	8.77	12:54-13:13	143.31	1,166.60	1.093	1,275	River Surveyor M9
2011/8/3	8.79	13:36-13:51	145.63	1,204.40	1.053	1,268	River Surveyor M9
2011/8/11	8.88	10:00-11:10	143.00	1,195.25	1.169	1,397	Propeller Current Meter
2011/8/16	9.39	10:00-11:20	144.00	1,257.30	1.186	1,491	Propeller Current Meter
2011/8/18	9.94	11:28-11:44	157.77	1,412.20	1.175	1,659	River Surveyor M9
2011/8/24	10.47	10:35-11:45	156.00	1,435.80	1.260	1,810	Propeller Current Meter
2011/8/31	11.04	10:45-12:00	163.00	1,540.20	1.382	2,129	Propeller Current Meter
2011/9/2	11.51	11:57-12:02	168.09	1,646.80	1.292	2,127	Propeller Current Meter
2011/9/7	11.96	10:30-12:30	163.00	1,662.10	1.431	2,378	River Surveyor M9
2011/9/9	12.24	10:33-10:49	169.16	1,672.30	1.433	2,396	River Surveyor M9
2011/9/22	13.03	13:13-13:31	163.36	1,761.20	1.558	2,743	River Surveyor M9
2011/10/28	13.00	10:30-12:00	176.00	1,793.45	1.636	2,934	Propeller Current Meter
2011/10/28	13.00	12:49-13:04	167.33	1,940.40	1.490	2,890	River Surveyor M9
2011/11/24	9.97	09:30-10:30	155	1,432.00	1.127	1,614	Propeller Current Meter

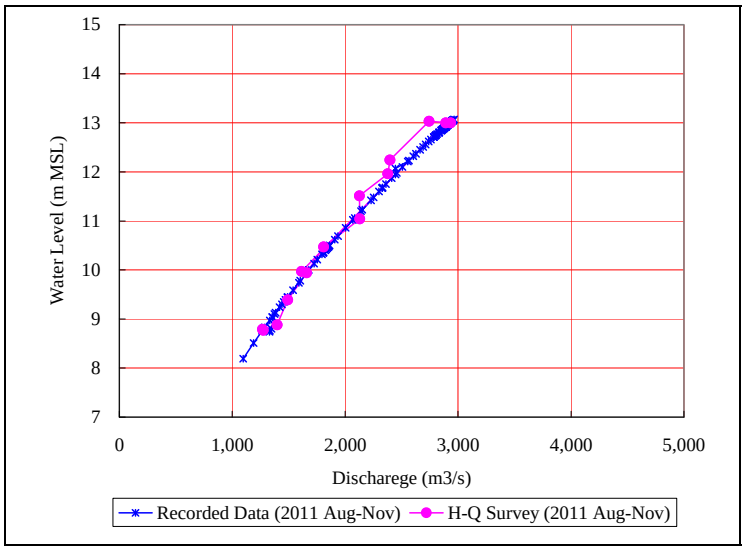


Figure T1.4.7 Recorded Data and H-Q Survey at C3 (Sing Buri)

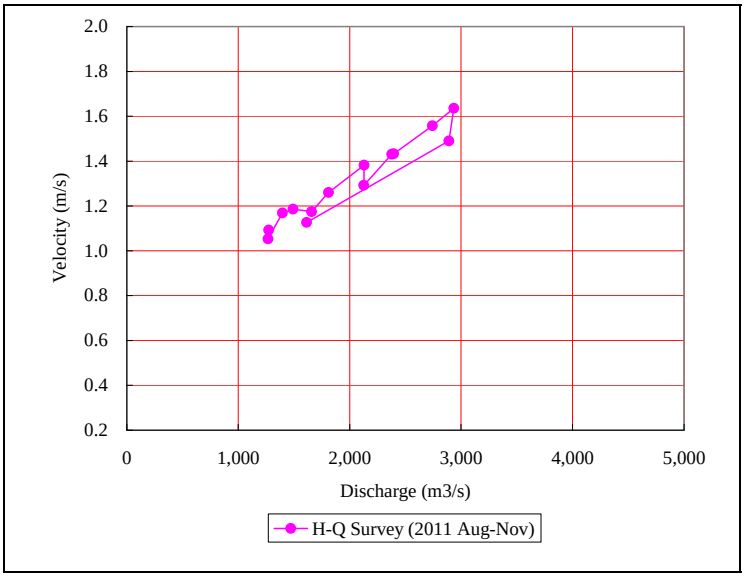


Figure T1.4.8 Velocity Measurement by H-Q Survey C3 (Sing Buri)

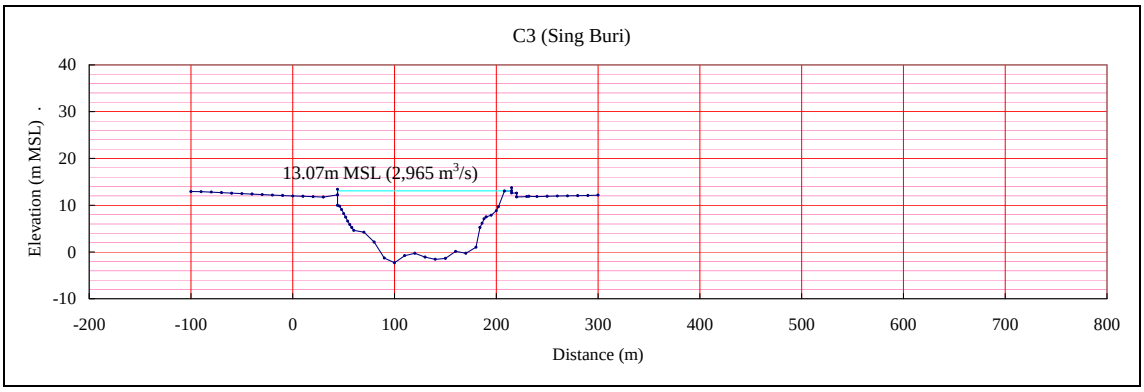


Figure T1.4.9 Cross Section of H-Q Survey at C3 (Sing Buri)

(1) According to Figure T1.4.7, the Recorded Data in 2011 is reasonable as it is based on H-Q Survey results generated by ADCP and propeller current meter.

T1.4.4 C7A (Ang Thong)

H-Q survey were conducted 7 times at C7A（Ang Thong） from August to November 2011 as shown in Table T 1.4.4. The comparison of water level measurement between Recorded Data and H-Q Survey data is shown in Figure T1.4.10, while velocity measurement by H-Q Survey is shown in Figure T1.4.11. Figure T1.4.12 shows the cross-section at C7A where H-Q Survey is taken.

Table T 1.4.4 H-Q Survey between August to November 2011 at C7A (Ang Thong)

Date	Level (m MSL)	Survey Time	Water Surface Width (m)	Area (m2)	Velocity (m/s)	Discharge (m3/s)	H-Q Survey Method
2011/8/5	5.91	09:25-10:55	115.00	865.20	1.423	1,231	
2011/8/9	5.51	12:35-14:05	113.00	820.20	1.338	1,097	
2011/8/19	6.80	11:30-13:10	120.00	970.90	1.493	1,449	Propeller Current Meter
2011/8/26	7.05	12:20-13:50	121.50	1,005.48	1.556	1,565	Propeller Current Meter
2011/9/15	9.21	10:45-13:15	131.00	1,274.60	1.835	2,339	Propeller Current Meter
2011/9/27	9.09	13:05-13:55	131.00	1,261.00	1.835	2,314	Propeller Current Meter
2011/10/19	9.26	-	-	1,370.50	1.779	2,438	River Surveyor M9

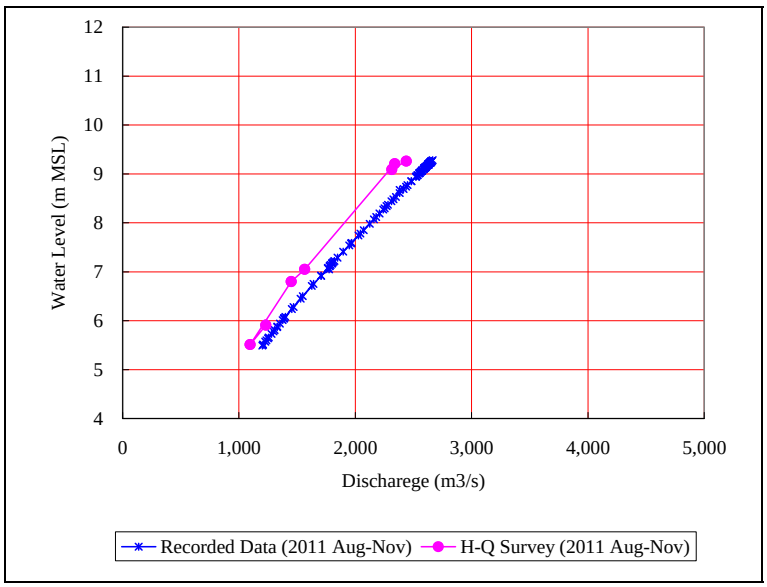


Figure T1.4.10 Recorded Data and H-Q Survey at C7A (Ang Thong)

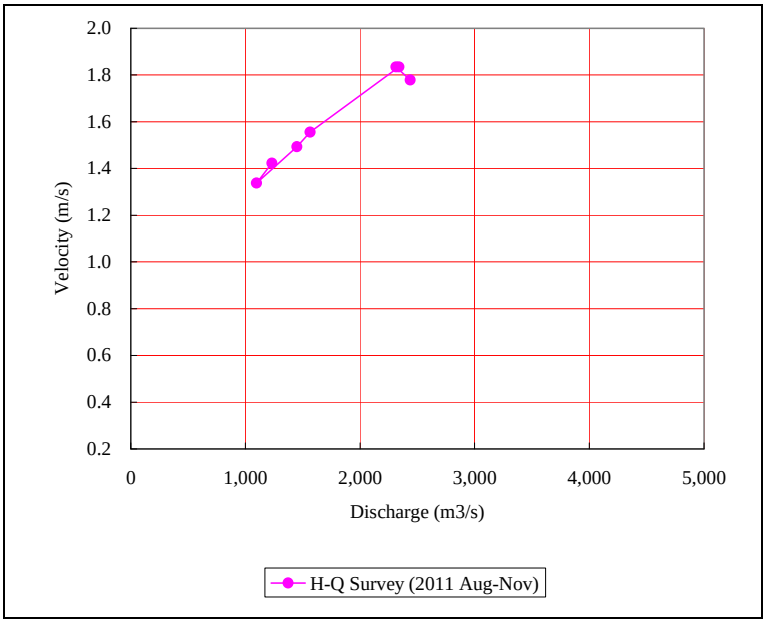


Figure T1.4.11 Velocity Measurement by H-Q Survey at C7A (Ang Thong)

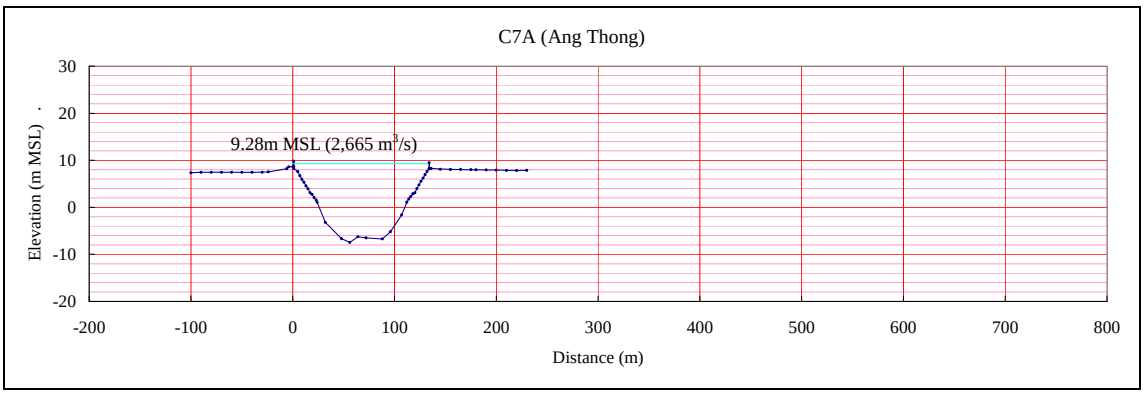


Figure T1.4.12 Cross Section of H-Q Survey at C7A (Ang Thong)

(1) According to Figure T1.4.10, the Recorded Data in 2011 is approximately 10 percent lower than H-Q Survey results. According to Hydro5 officer, this is due to the H-Q Curve they used for discharge calculation. For Recorded Data in 2011, the discharge was calculated from the 2010 H-Q Curve. Therefore, the records were different from the H-Q Survey results taken in 2011.

(2) C7A station is located in Ang Thong. The station condition is summarized below.

C7A: Ang Thon (14°35'25.79", 100°27'18.55")　Chao Phraya River

- There are hydrological stations of RID and DWR located approximately 100 apart from each other.
- There is no HAII station at this site.
- H-Q Survey is conducted by boat (survey direction is fixed: from left to right bank).

C7A RID Telemetry Station (Left Bank)

C7A RID Telemetry Station

C7A RID Staff Gauge

Parapet Wall: Height before Heightening

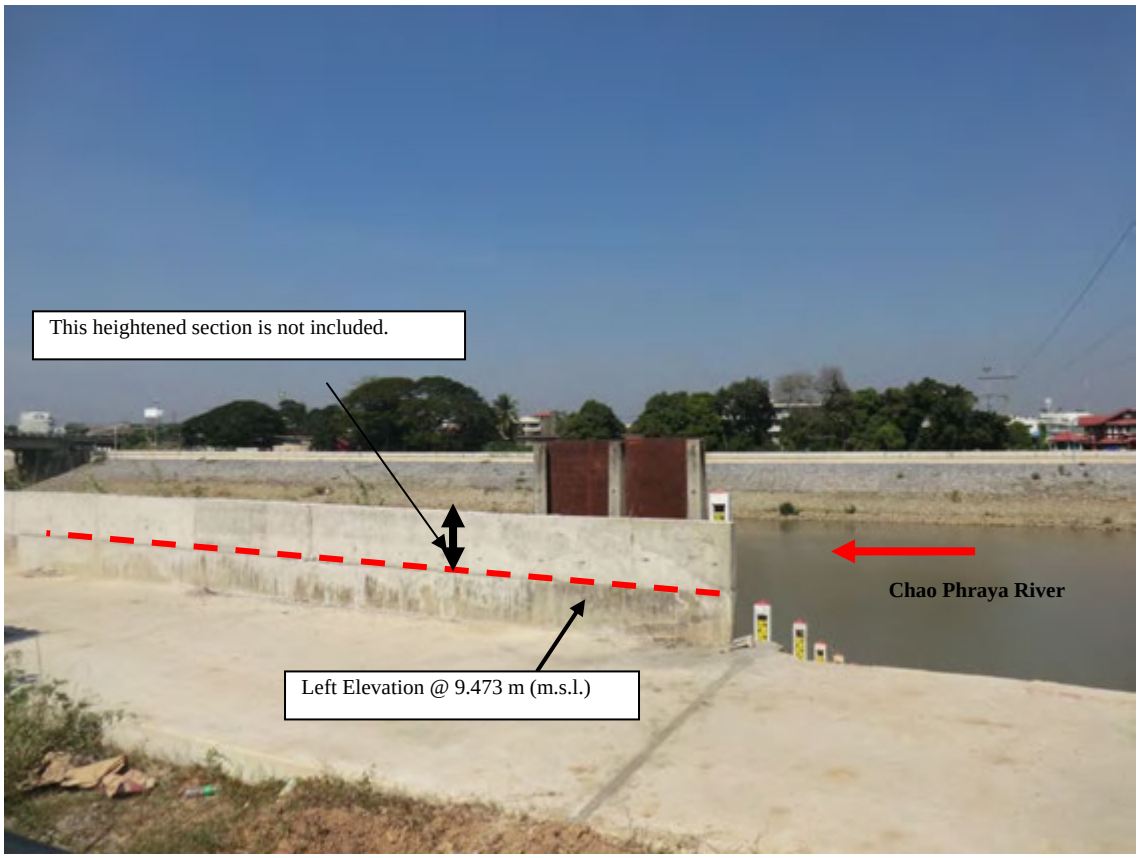
Looking from C7A at a Bridge where H-Q Survey is Conducted.

Location of H-Q Survey at C7A

	
Flood Warning Panel Installed on Left Bank at C7A	Flood Warning Panel Installed on Left Bank at C7A
	
DWR Telemetry Station	DWR Telemetry Station

Bank Elevation (M.S.L.)

1. 2011 H-Q Curve: Right Elevation @ 9.816 m (m.s.l.), Left Elevation @ 9.473 m (m.s.l.)
2. For both right and left banks, the elevation is the height of the parapet wall without the heightened section. The heightened sections are added after the 2011 flood.



T1.4.5 C35 (Ayutthaya)

H-Q survey were conducted 13 times at C35（Ayutthaya） from August to November 2011 as shown in Table T 1.4.5. The comparison of water level measurement between Recorded Data and H-Q Survey data is shown in Figure T1.4.13, while velocity measurement by H-Q Survey is shown in Figure T1.4.14. Figure T1.4.15 shows the cross-section at C35 where H-Q Survey is taken.

Table T 1.4.5 H-Q Survey between August to November 2011 at C35 (Ayutthaya)

Date	Level (m MSL)	Survey Time	Water Surface Width (m)	Area (m2)	Velocity (m/s)	Discharge (m3/s)	H-Q Survey Method
2011/8/4	2.97	12:20-13:25	107.00	626.05	1.436	899	
2011/8/8	2.82	08:30-09:30	105.00	615.20	1.554	956	
2011/8/18	3.26	12:20-13:45	110.00	657.70	1.566	1,030	
2011/8/25	3.58	08:40-10:05	114.00	691.55	1.697	1,174	Propeller Current Meter
2011/8/31	3.90	08:55-10:15	115.50	724.75	1.751	1,269	Propeller Current Meter
2011/9/2	4.28	08:40-09:45	132.00	782.50	1.774	1,365	
2011/9/6	4.46	12:30-13:40	139.00	795.35	1.752	1,393	
2011/9/14	5.11	08:30-09:45	143.00	883.50	1.674	1,479	Propeller Current Meter
2011/9/28	5.18	08:45-09:35	143.00	893.65	1.588	1,419	Propeller Current Meter
2011/10/5	5.43	08:45-09:45	144.00	928.55	1.446	1,342	Propeller Current Meter
2011/11/21	4.64	13:45-14:30	141.00	824.60	1.252	1,033	
2011/11/22	4.55	11:35-12:30	140.00	812.30	1.293	1,049	
2011/11/30	3.64	10:20-11:15	114.00	697.55	1.160	809	Propeller Current Meter

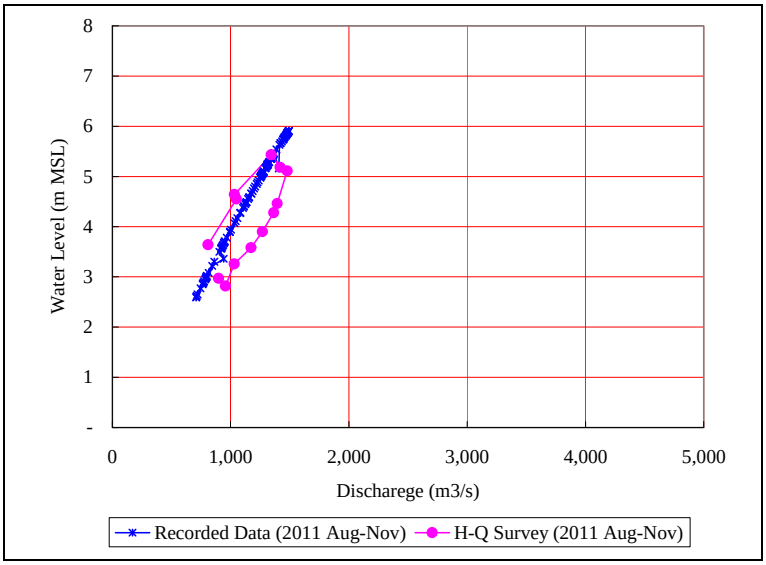


Figure T1.4.13 Recorded Data and H-Q Survey at C35 (Ayutthaya)

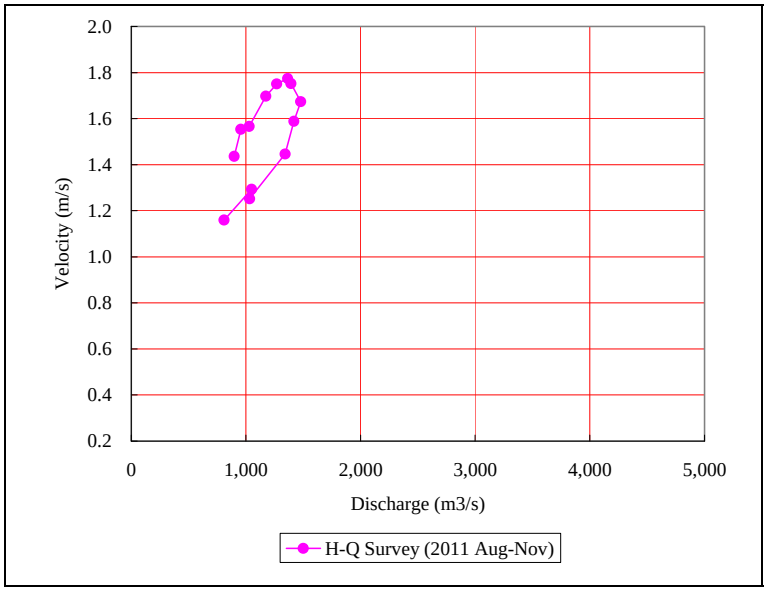


Figure T1.4.14 Velocity Measurement by H-Q Survey at C35 (Ayutthaya)

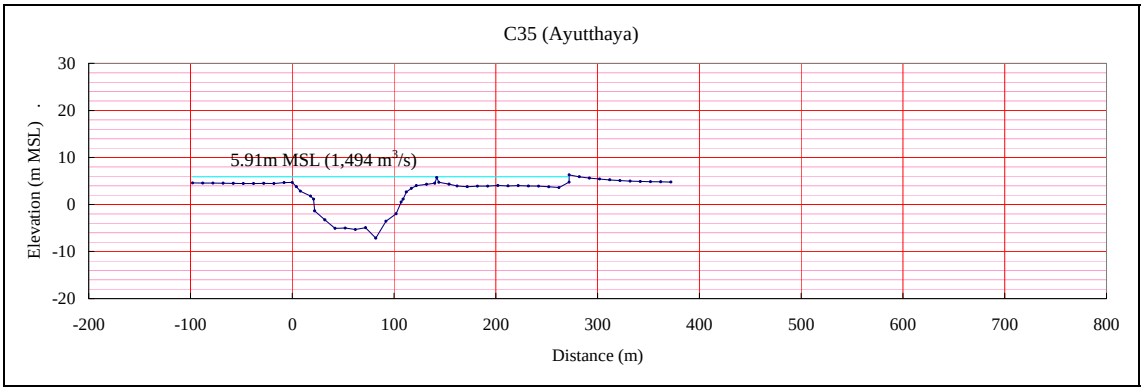


Figure T1.4.15 Cross Section of H-Q Survey at C35 (Ayutthaya)

(1) As shown in Figure T1.4.13, H-Q measurement results are not consistent. According to Hydro 5 officer, this is due to the backwater effect at the confluence of the Pasak River which is located just downstream of C35. It is also assumed that discharge records in 2011 contain some erroneous values.

(2) The peak discharge in 2011 at C35 was 1,494 m^3/s. It must be note that this peak discharge is consider to be much smaller than the actual discharge occurred during the 2011 Flood. According to the RID record, the top elevation of channel bank (the primary dyke) is approximately 4.7 to 5.7 m MSL. During the 2011 Flood, the maximum water level was 5.91 m MSL, which indicates that the water overflowed banks in adjacent areas. However, the maximum width of water surface from H-Q Survey was 144 m, roughly equal to the water surface width at bankfull flow. The peak discharge of 1,494 m^3/s was calculated based on only the water volume within the channel (which means this record is not taking into account the volume of overflowed water). Therefore, it is concluded that the actual peak discharge could be much larger than the recorded peak discharge of 1,494 m^3/s.

T1.4.6 C36 (Phong Peng Canal)

H-Q survey were conducted 12 times at C36（Phong Peng Canal） from August to November 2011 as shown in

Table T 1.4.6. The comparison of water level measurement between Recorded Data and H-Q Survey data is shown in Figure T1.4.16, while velocity measurement by H-Q Survey is shown in Figure T1.4.17. Location map of H-Q Survey at C36 is shown in Figure T1.4.18. Figure T1.4.19 shows the cross-section at C36 where H-Q Survey is taken. Also, additional cross-sections which are located upstream and downstream of C36 are shown in Figure T1.4.20 and Figure T1.4.21, respectively.

Table T 1.4.6 H-Q Survey between August to November 2011 at C36 (Phong Peng Canal)

Date	Level (m MSL)	Survey Time	Water Surface Width (m)	Area (m2)	Velocity (m/s)	Discharge (m3/s)	H-Q Survey Method
2011/8/4	4.04	13:45 - 14:30	83.00	503.25	0.832	419	
2011/8/8	4.09	09:55 - 10:40	83.50	508.45	0.843	429	
2011/8/18	4.61	14:05 - 15:00	152.00	595.60	0.918	547	
2011/8/25	5.06	10:20 - 11:20	155.00	654.90	0.878	575	Propeller Current Meter
2011/9/2	5.77	10:20 - 11:25	158.50	763.93	0.998	763	
2011/9/6	6.00	14:00 - 15:05	159.00	793.85	1.015	806	
2011/9/14	6.44	10:05 - 11:10	160.00	855.60	1.165	996	
2011/9/28	6.39	09:55 - 10:45	160.00	842.00	1.167	983	Propeller Current Meter
2011/10/4	6.45	14:15 - 15:10	160.00	859.20	1.129	970	Propeller Current Meter
2011/11/21	5.41	11:10 - 12:05	157.00	702.00	0.962	675	
2011/11/22	5.31	14:30 - 15:10	156.50	685.23	0.923	633	
2011/11/30	4.32	13:20 - 13:50	108.30	531.20	0.681	362	Propeller Current Meter

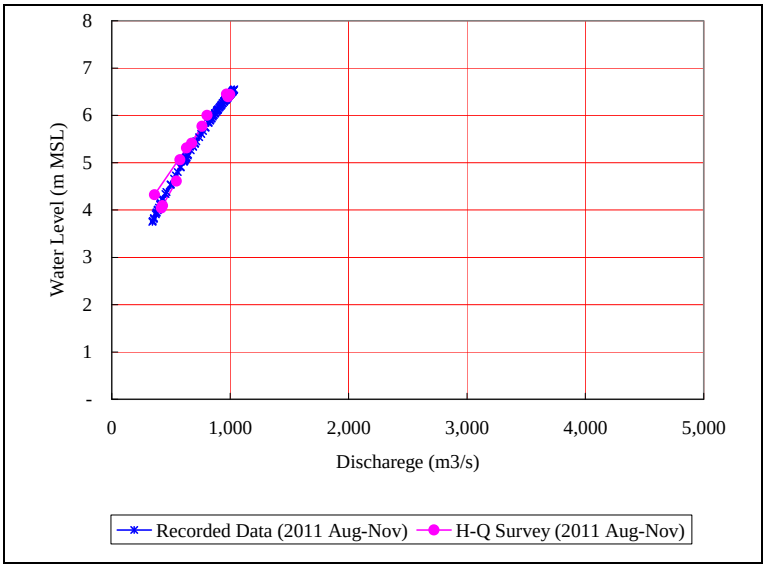


Figure T1.4.16 Recorded Data and H-Q Survey at C36 (Phong Peng Canal)

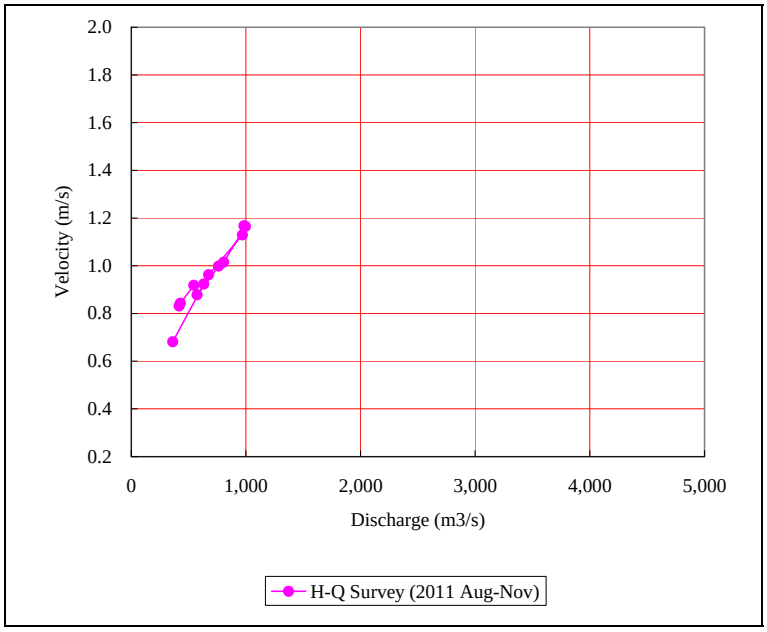


Figure T1.4.17 Velocity Measurement by H-Q Survey at C36 (Phong Peng Canal)

Figure T1.4.18 Location Map of H-Q Survey (03B0080) at C36 (Phong Peng Canal) and Cross-Sections Located Upstream and Downstream of C36

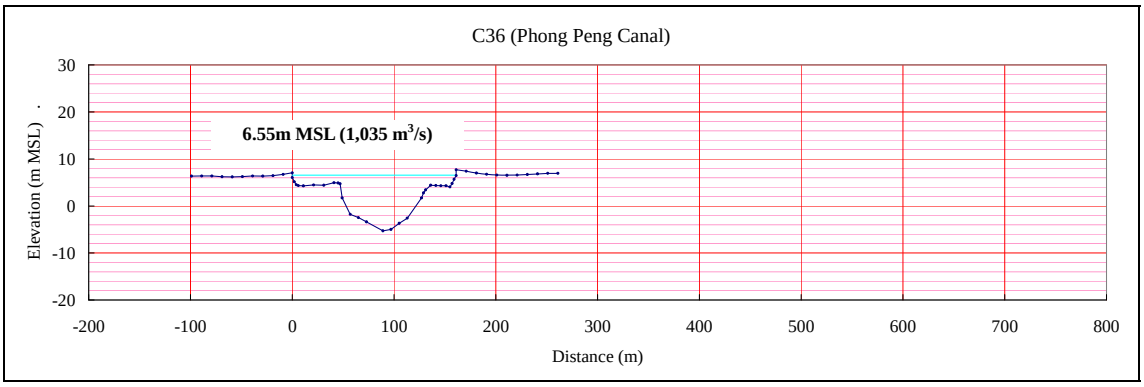


Figure T1.4.19 Cross Section of H-Q Survey (03B0080) at C36 (Phong Peng Canal)

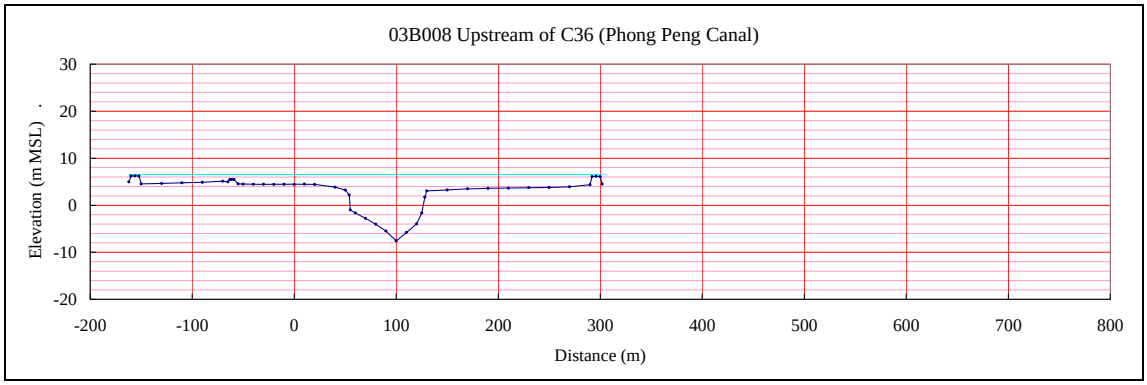


Figure T1.4.20 Cross Section at 03B008 (Right Upstream of C36)

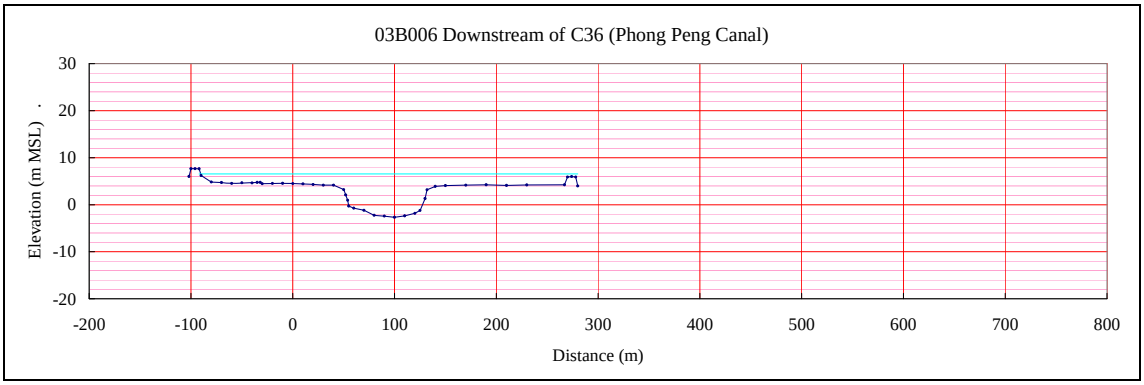


Figure T1.4.21 Cross Section at 03B006 (Right Downstream of C36)

(1) According to Figure T1.4.16, the Recorded Data in 2011 is reasonable as it is based on H-Q Survey results generated by propeller current meter.

(2) The peak discharge in 2011 at C36 was 1,035 m^3/s. It must be noted that this peak discharge is considered to be much smaller than the actual discharge occurred during the 2011 Flood. According to the RID record, the top elevation of channel bank (the primary dyke) is approximately 7.1 to 7.7 m MSL. However these heights actually indicate the elevation of bridge abutment, not the bank elevation. The top elevation of the bank is about 4.0 m for both upstream and downstream sides. During the 2011 Flood, the maximum water level was 6.55 m MSL, which indicates that the water overflowed banks both upstream and downstream of C36 station. However, the maximum width of water surface from H-Q Survey was 144 m, roughly equal to the water surface width at bankfull flow. The peak discharge of 1,035 m^3/s was calculated based on the water volume only within the channel (which means this record is not taking into account the volume of overflowed water). Therefore, it is concluded that the actual peak discharge could be much larger than the recorded peak discharge of 1,035 m^3/s.

(3) C36 station is located in Bang Luang Dot. The station condition is summarized below.

C36: Bang Luang Dot (14°24' 58.27", 100°26' 25.79") Bang Luang River

- Hydrological Stations of RID, DOR, and HAII are installed right next to each other on the bridge
- H-Q Survey is conducted by using Propeller Current Meter from the bridge. Boat measurement is not taken at this section. (measurement by Propeller Current Meter is conducted from right to left bank)

RID Telemetry Station (Downstream)

Right Bank, Residence located Upstream of the Bridge

Right Bank, Upstream of the Bridge (Water Mark: 6.3 m MSL)

Right Bank, Downstream of the Bridge

T1.4.7 C37 (Bang Ban Canal)

H-Q survey were conducted 13 times at C37 (Bang Ban Canal) from August to November 2011 as shown in Table T 1.4.7. The comparison of water level measurement between Recorded Data and H-Q Survey data is shown in Figure T1.4.22, while velocity measurement by H-Q Survey is shown in Figure T1.4.23. Location map of H-Q Survey at C37 is shown in Figure T1.4.24. Figure T1.4.25 shows the cross-section at C37 where H-Q Survey is taken. Also, additional cross-sections which are located upstream and downstream of C37 are shown in Figure T1.4.26 and Figure T1.4.27, respectively.

Table T 1.4.7 H-Q Survey between August to November 2011 at C37 (Bang Ban Canal)

Date	Level (m MSL)	Survey Time	Water Surface Width (m)	Area (m2)	Velocity (m/s)	Discharge (m3/s)	H-Q Survey Method
2011/8/4	3.25	14:40 - 15:10	51.00	166.55	0.588	98	
2011/8/8	3.28	10:50 - 11:25	51.00	168.35	0.609	103	
2011/8/18	3.68	15:10 - 15:55	170.00	230.08	0.517	119	
2011/8/25	4.11	11:35 - 12:20	172.50	293.00	0.455	133	Propeller Current Meter
2011/9/2	4.81	11:40 - 12:25	175.00	407.95	0.466	190	
2011/9/6	5.05	15:15 - 16:00	176.50	440.58	0.464	204	
2011/9/14	5.45	11:20 - 12:05	177.50	505.88	0.538	272	
2011/9/26	5.31	15:20 - 16:05	177.50	489.75	0.605	296	Propeller Current Meter
2011/10/5	5.39	10:00 - 10:40	177.50	490.50	0.643	316	Propeller Current Meter
2011/11/16	4.94	14:40 - 15:20	175.00	419.45	0.525	220	
2011/11/21	4.69	12:45 - 13:10	174.00	384.40	0.487	187	
2011/11/22	4.63	13:15 - 13:50	174.00	372.50	0.450	168	
2011/11/30	3.86	14:05 - 14:30	171.00	248.55	0.382	95	Propeller Current Meter

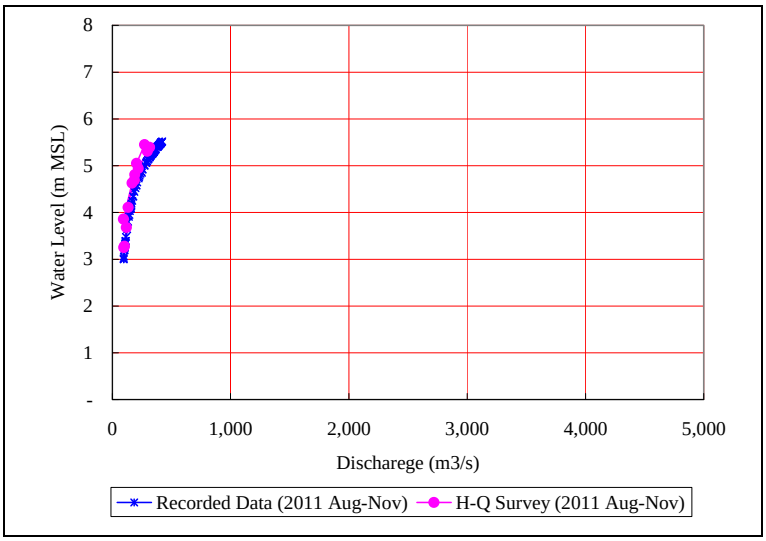


Figure T1.4.22 Recorded Data and H-Q Survey at C37 (Bang Ban Canal)

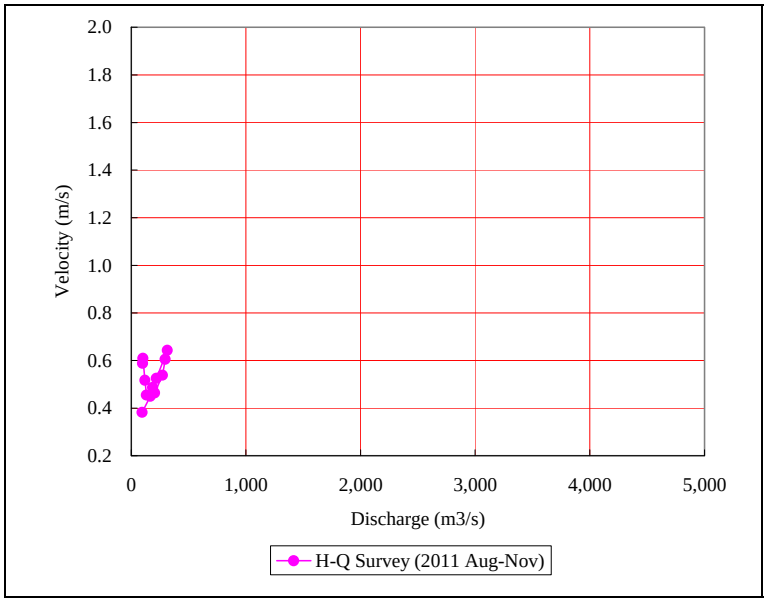


Figure T1.4.23 Velocity Measurement by H-Q Survey at C37 (Bang Ban Canal)

Figure T1.4.24 Location Map of H-Q Survey (01B0090) at C37 (Bang Ban Canal) and Cross-Sections Located Upstream and Downstream of C37

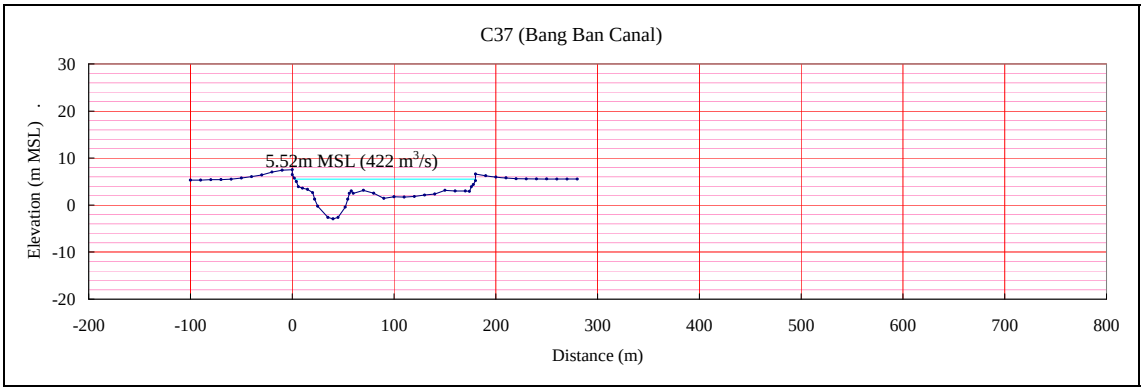


Figure T1.4.25 Cross Section of H-Q Survey at C37 (Bang Ban Canal)

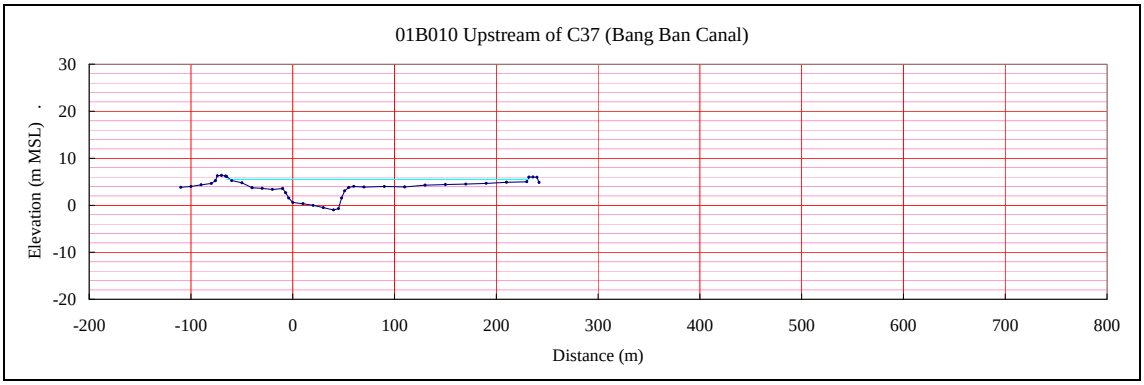


Figure T1.4.26 Cross Section at 01B010 (Right Upstream of C37)

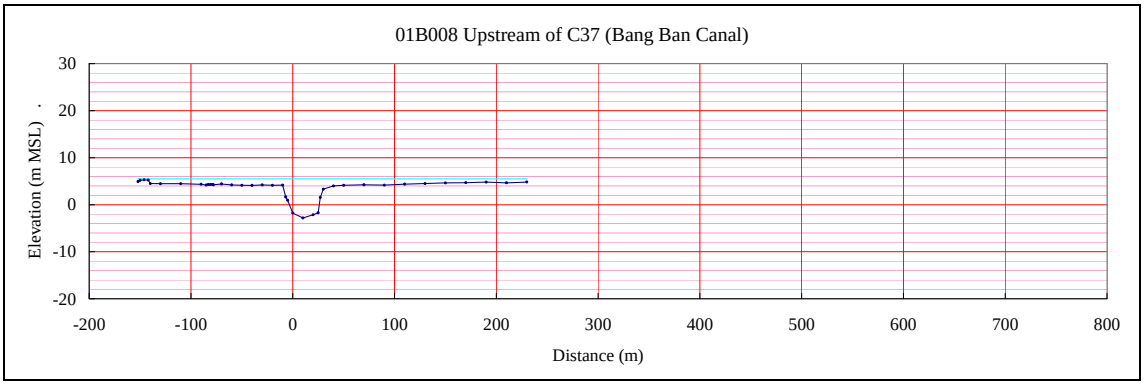


Figure T1.4.27 Cross Section at 01B008 (Right Downstream of C37)

(1) According to Figure T1.4.22, the Recorded Data in 2011 is reasonable as it is based on H-Q Survey results generated by propeller current meter.

(2) The peak discharge in 2011 at C37 was 422 m^3/s. It must be noted that this peak discharge is considered to be much smaller than the actual discharge occurred during the 2011 Flood. According to the RID record, the top elevation of both banks (the primary dyke) is approximately 5.4 (Right Bank) to 5.7m MSL (Left Bank), however these heights actually indicate the elevations of bridge abutment. The top elevation of the dyke is about 4.0 m for both upstream and downstream sides. During the 2011 Flood, the maximum water level was 5.52 m MSL, which indicates that the water overflowed banks both upstream and downstream of C37 station. However, the maximum width of water surface from H-Q Survey was 178 m, roughly equal to the water surface width at bankfull flow. The peak discharge of 422 m^3/s was calculated based on the water volume only within the channel (which means this record is not taking into account the volume of overflowed water). Therefore, it is concluded that the actual peak discharge could be much larger than the recorded peak discharge of 422 m^3/s.

(3) C37 station is located in Bang Ban. The station condition is summarized below.

C37: Bnag Ban (14°21' 46.80", 100°29'6.33") Bang Ban River

- RID Hydrological Station is installed on the side of the bridge.
- Hydrological Stations of DOR, DWR, and HAII are not installed at this location.
- H-Q Survey is conducted by using Propeller Current Meter from the bridge. Boat measurement is not taken at this section. (measurement by Propeller Current Meter is taken from left to right bank)

Left Bank, Upstream of the Bridge
(Water Mark: 5.4 m MSL)

Looking Downstream from the Bridge
(Tidal Effect on the flow direction (adverse current) is indicated by the dotted arrow)

The Bridge over the Channel

Looking Upstream from the Bridge
(Tidal Effect on the flow direction (adverse current) is indicated by the dotted arrow)

T1.4.8 S5 (Pa Sak River, Ayutthaya)

H-Q survey were conducted 9 times at S5（Pa Sak River, Ayutthaya） from August to November 2011 as shown in Table T 1.4.8. The comparison of water level measurement between Recorded Data and H-Q Survey data is shown in Figure T1.4.28, while velocity measurement by H-Q Survey is shown in Figure T1.4.29. Figure T1.4.30 shows the cross-section at S5 where H-Q Survey is taken.

Table T 1.4.8 H-Q Survey between August to November 2011 at S5 (Pa Sak River, Ayutthaya)

Date	Level (m MSL)	Survey Time	Water Surface Width (m)	Area (m2)	Velocity (m/s)	Discharge (m3/s)	H-Q Survey Method
2011/8/4	2.57	15:45 - 17:05	96.00	719.76	0.922	664	
2011/8/9	1.87	08:50 - 10:00	96.00	657.13	0.547	359	
2011/8/19	2.59	08:40 - 09:30	96.00	718.98	0.672	483	
2011/8/26	2.77	08:35 - 09:45	96.00	737.36	0.665	490	Propeller Current Meter
2011/9/7	3.63	08:40 - 09:55	96.00	806.98	0.859	693	
2011/9/23	4.43	11:35 - 13:00	96.00	877.38	1.331	1,168	Propeller Current Meter
2011/10/4	5.20	12:35 - 13:25	96.00	947.01	1.787	1,692	Propeller Current Meter
2011/11/16	4.84	13:15 - 14:10	96.00	911.81	1.374	1,252	
2011/11/30	3.64	11:35 - 12:20	96.00	806.21	0.966	779	Propeller Current Meter

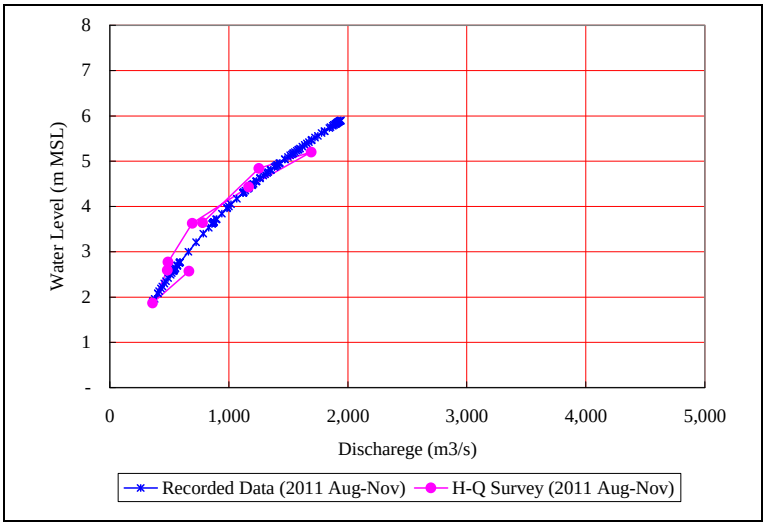


Figure T1.4.28 Recorded Data and H-Q Survey at S5 (Pa Sak River, Ayutthaya)

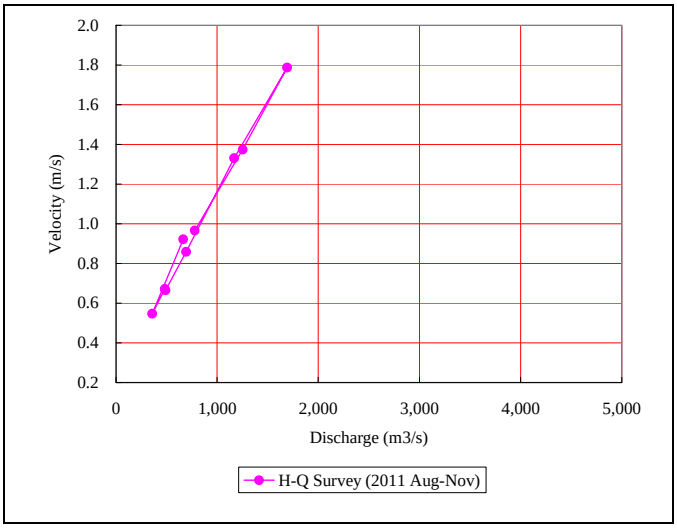


Figure T1.4.29 Velocity Measurement by H-Q Survey at S5 (Pa Sak River, Ayutthaya)

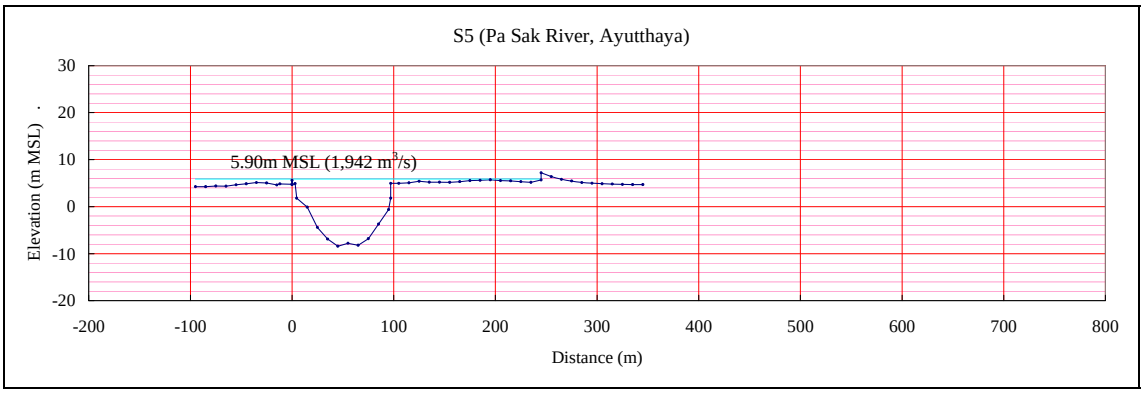


Figure T1.4.30 Cross Section of H-Q Survey at S5 (Pa Sak River, Ayutthaya)

(1) According to Figure T1.4.28, the Recorded Data in 2011 is reasonable as it is based on H-Q Survey results generated by propeller current meter.

(2) The peak discharge in 2011 at S5 was 1,942 m^3/s. It must be noted that this peak discharge is considered to be much smaller than the actual discharge occurred during the 2011 Flood. According to the RID record, the top elevation of both banks (the primary dyke) is approximately 5.1 m MSL (including the height of parapet wall). During the 2011 Flood, the maximum water level was 5.90 m MSL, which indicates that the water overflowed banks both upstream and downstream of S5 station. However, the maximum width of water surface from H-Q Survey was 96 m, roughly equal to the water surface width at bankfull flow. The peak discharge of 1,942 m^3/s was calculated based on the water volume only within the channel (which means this record is not taking into account the volume of overflowed water). Therefore, it is concluded that the actual peak discharge could be much larger than the recorded peak discharge of 1,942m^3/s.

(3) In 2011, the Rama VI regulator, located approximately 50 km upstream of S5, released the peak outflow of approx. 1,300m^3/s, whereas the peak discharge at S5 was 1,942 m^3/s. Based on these records, the difference in the peak discharge between two stations is 640m^3/s. Moreover, it was recorded that after the mid October, the discharge difference was more than 1,000m^3/s as shown in Figure T1.4.31. The reason behind these discharge differences is that it is assumed the overflowed water in upstream basin (around Chai Nat) was flowing southward, and then flowing back into the Pa Sak River which increased the discharge at S5.

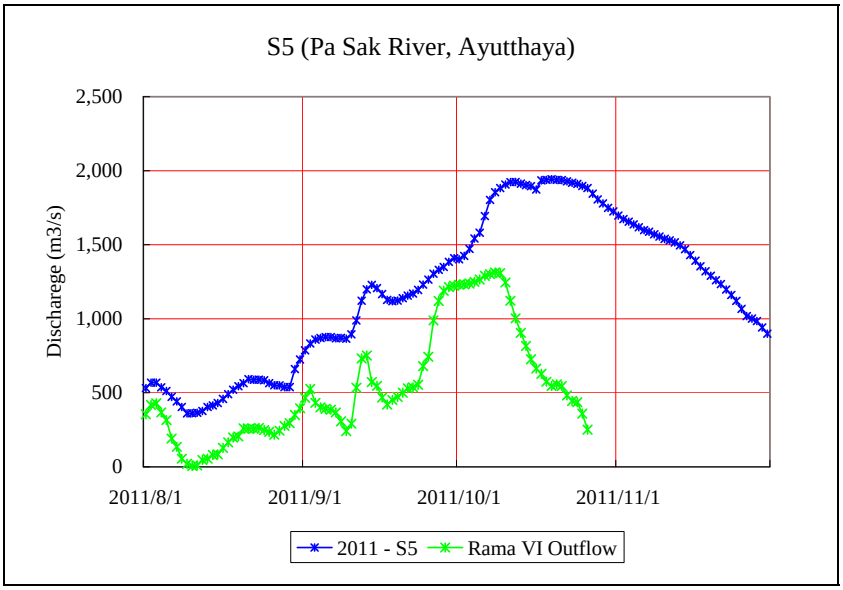


Figure T1.4.31 Discharge Comparison between S5and Rama VI Regulator

(4) S5 station is located in Ayutthaya. The station condition is summarized below.

S5: Ayutthaya (14°21' 6.21", 100°34' 51.97") Pa Sak River	
─Hydrological Stations of RID and DWR are installed on the side of the bridge ─Hydrological Stations of DOR and HAII are not installed at this location. ─H-Q Survey is conducted by using Propeller Current Meter from the bridge. Boat measurement is not taken at this section. (measurement by Propeller Current Meter is conducted from right to left bank) ─At the time of field survey (1PM on December 21, 2012), the tidal effect (adverse current) is recoded at this station.	
	
RID Telemetry Station, Downstream of the Bridge (Tidal Effect on the flow direction (adverse current) is indicated by the dotted arrow)	DWR Telemetry Station, Installed Downstream of the Bridge

T1.4.9 S26 (Pa Sak River, Downstream of Rama VI Barrage)

H-Q survey were conducted 9 times at S26 (Pa Sak River, Downstream of Rama VI Barrage) from August to November 2011 as shown in Table T 1.4.9. The comparison of water level measurement between Recorded Data and H-Q Survey data is shown in Figure T1.4.32, while velocity measurement by H-Q Survey is shown in Figure T1.4.33. Figure T1.4.34 shows the cross-section at S26 where H-Q Survey is taken.

Table T 1.4.9 H-Q Survey between August to November 2011 at S26 (Downstream of Rama VI Barrage)

Date	Level (m MSL)	Survey Time	Water Surface Width (m)	Area (m2)	Velocity (m/s)	Discharge (m3/s)	H-Q Survey Method
2011/8/5	4.55	11:35-12:05	61.50	298.65	1.032	308	
2011/8/9	2.09	10:45-11:20	46.50	166.43	0.345	57	
2011/8/19	3.93	10:15-10:45	57.50	260.08	0.924	240	
2011/8/26	3.95	10:35-11:00	57.50	261.58	0.864	226	
2011/9/7	5.76	10:40-11:40	72.00	379.00	0.944	358	
2011/9/12	9.34	13:55-14:55	107.00	703.45	1.254	882	
2011/9/26	10.02	12:50-13:45	107.00	774.15	1.300	1,006	Propeller Current Meter
2011/10/19	9.11	13:30-14:15	107.00	686.75	0.989	679	Propeller Current Meter
2011/11/17	5.57	11:50-12:35	66.00	356.76	0.091	33	Propeller Current Meter

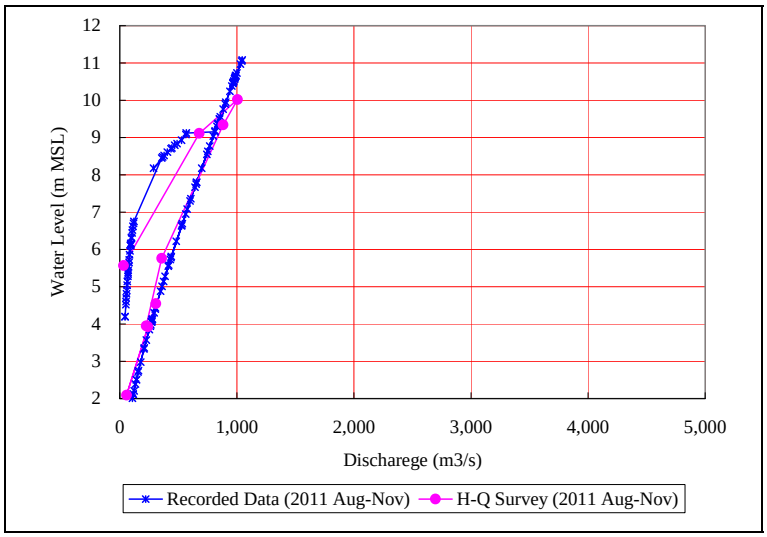


Figure T1.4.32 Recorded Data and H-Q Survey at S26 (Downstream of Rama VI Barrage)

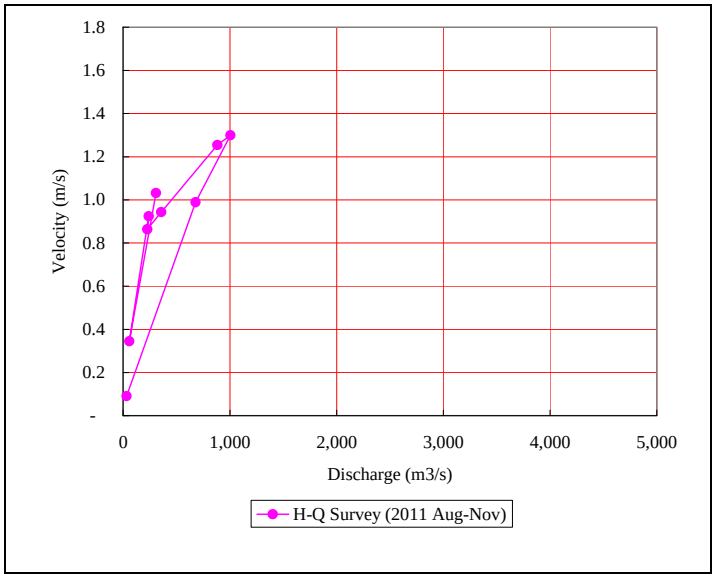


Figure T1.4.33 Velocity Measurement by H-Q Survey at S26 (Downstream of Rama VI Barrage)

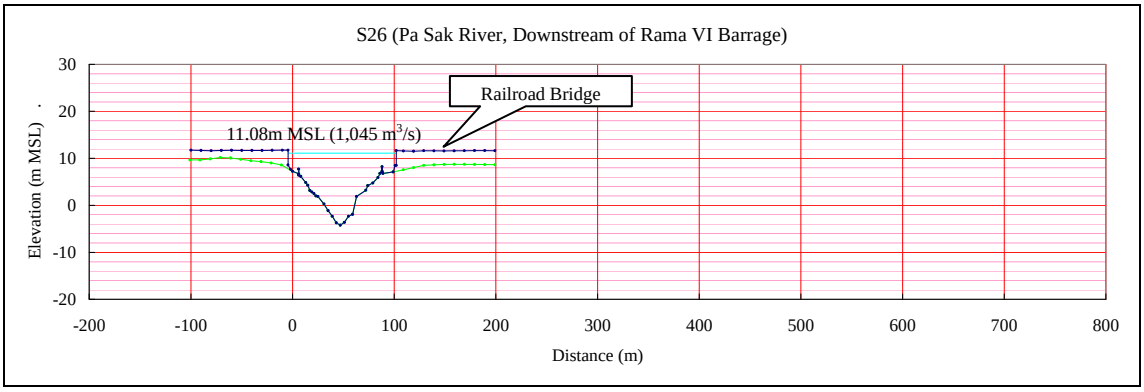


Figure T1.4.34 Cross Section of H-Q Survey at S26 (Downstream of Rama VI Barrage)

(1) The maximum water level recorded during the 2011 Flood was 11.08 m MSL (September 30). On the other hand, the elevations of railroad bridge abutments are 11.75 m MSL at left bank and 11.65 m MSL at right bank, which are higher than the flood level of 2011. However, looking at both upstream and downstream of the railroad bridge, there are parapet wall on both banks which top elevations are 7.72 m MSL (left bank) and 8.23 m MSL (right bank). In other words, the water overflowed parapet walls and inundated adjacent areas.

(2) Based on the H-Q Survey during the 2011 Flood, Hydro 5 Centre modified the H-Q curve. The modification includes the development of two curves, Curve 1: H-Q correlation when water level rises, and Curve 2: H-Q correlation when water level decreases. According to Table T 1.4.9, when the water level rises, for example on September 12, the water level was 9.34 m and discharge was 882 m^3/s. On the other hand, looking at the record of October 19 as an example of when the water level decreases, although the water level measurement was 9.11 m which is almost the same, the discharge was 679 m^3/s which is about 200 m^3/s less than the September measurement. Therefore, two H-Q curves were created in order to take into account the different H-Q correlations observed during the 2011 Flood. However, it is doubtful if the developed H-Q Curve 2 is reasonable as this is based on the H-Q Survey taken only twice during the water level decreasing period as shown in Figure T1.4.35. Therefore, it is also doubtful if the Recorded Data is reasonable or not, as the discharge in this Recorded Data is determined based on the H-Q curves.

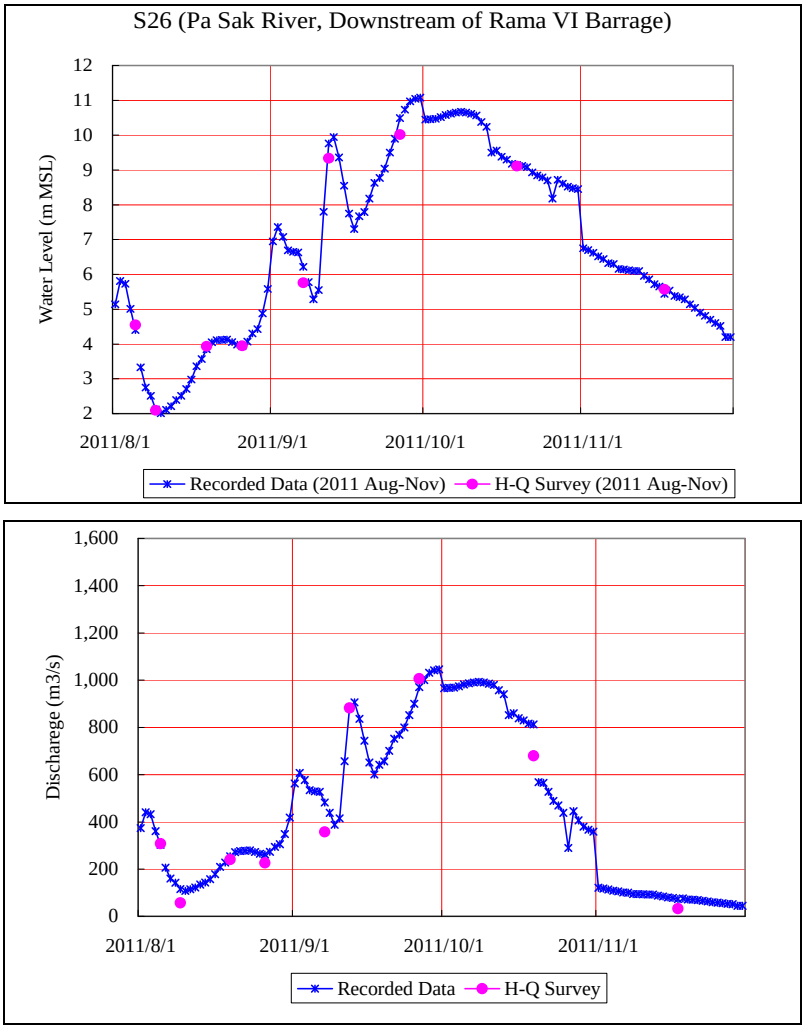


Figure T1.4.35 Recorded Data and H-Q Survey at S26

(3) Rama VI Barrage is located approximately 6 km upstream of S26. The water level and discharge comparisons between S26 and Rama VI Barrage are shown in Figure T1.4.36. Even though the water level measurements are almost the same, the outflow record at Rama VI Barrage differs substantially from the S26 discharge record. Therefore, it is concluded that the validity of using the modified H-Q curve (different H-Q curves are applied for 1) when the water level is rising and 2) when the water level is falling) is quite doubtful.

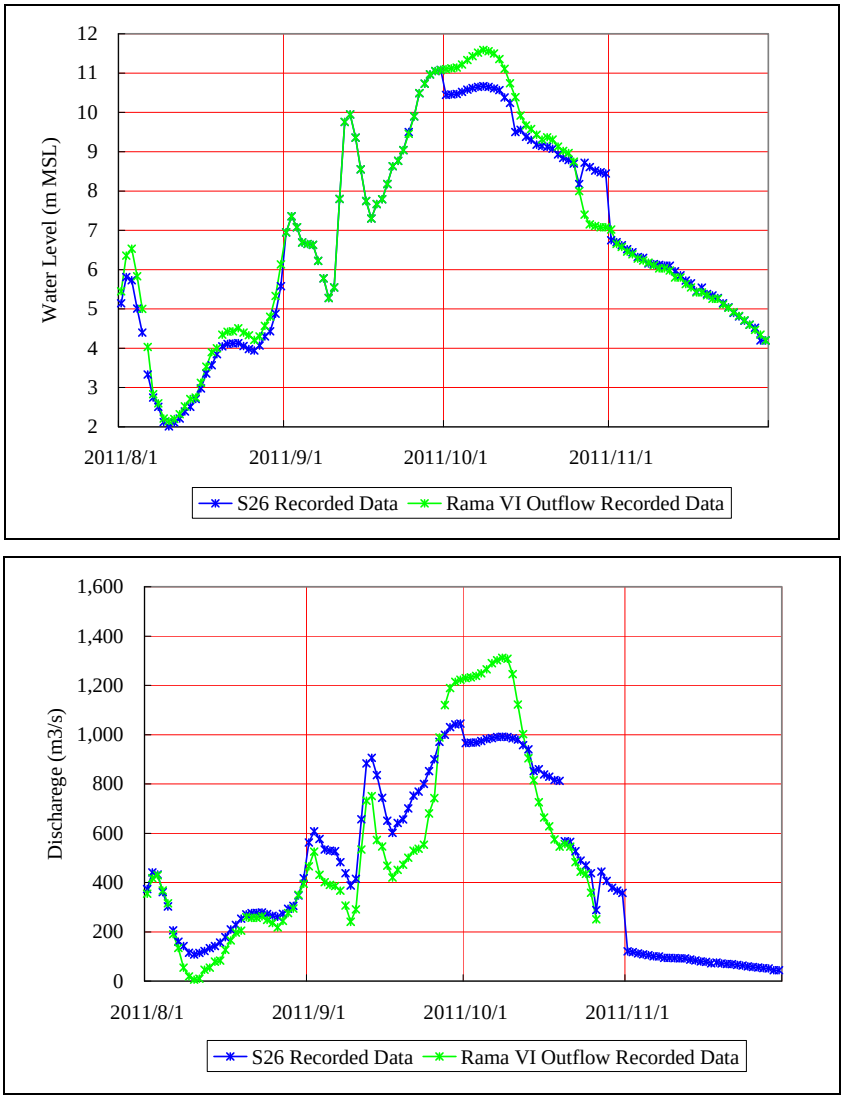
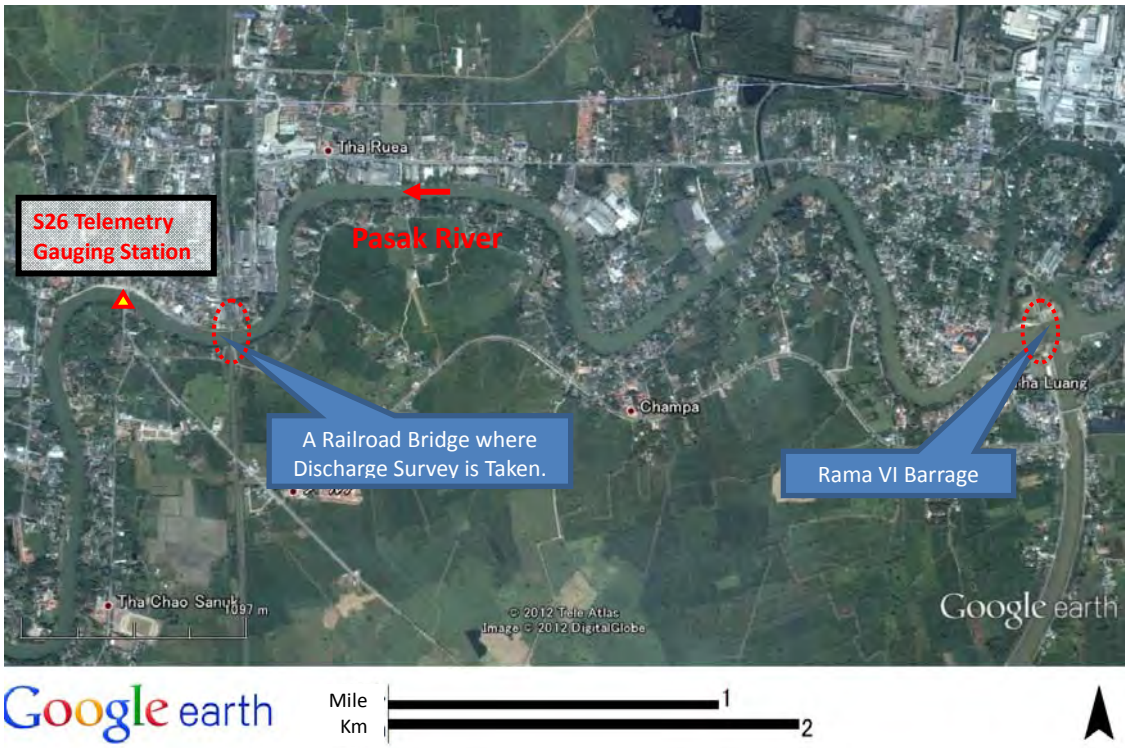
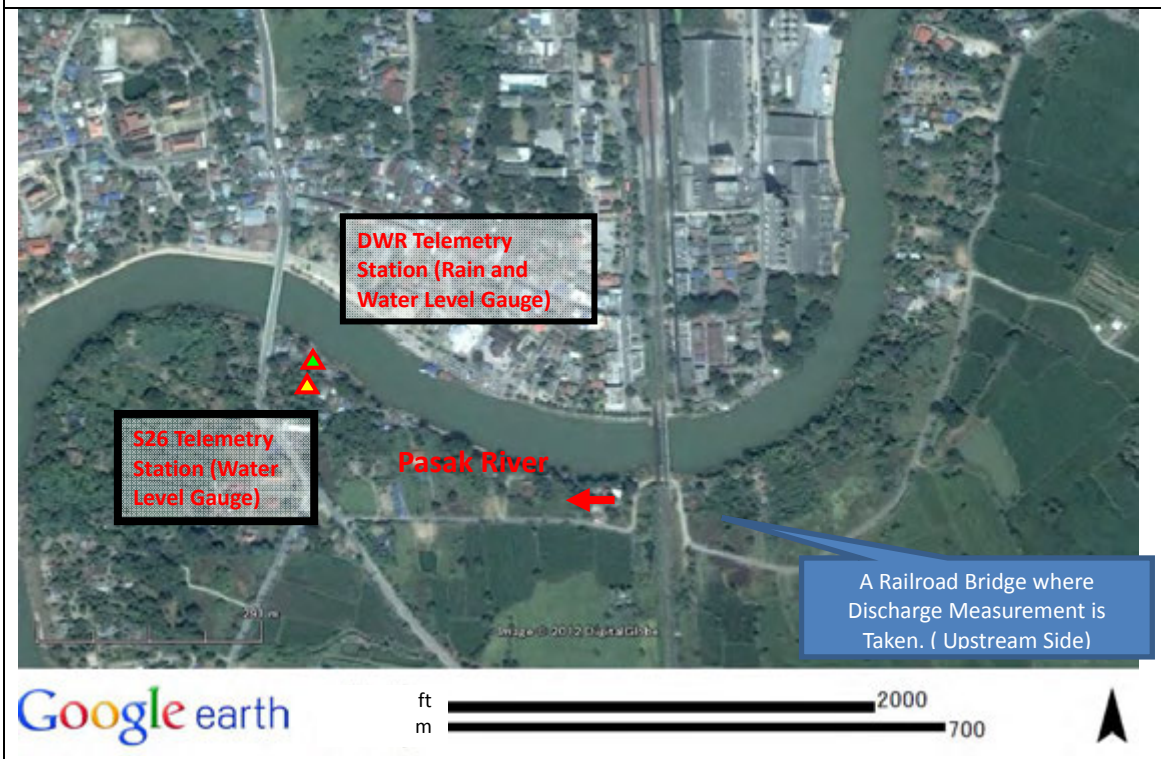


Figure T1.4.36 Water Level and Discharge Comparisons between S26 and Rama VI Barrage

(4) S26 station is located downstream of Rama VI Barrage. The station condition is summarized below.

S26: Downstream of Ram VI Barrage、Pa Sak River





- S26 Telemetry Water Level Gauge is installed on the road bridge located approximately 6.5 km downstream of the Rama VI Barrage. On the other hand, discharge measurement is taken at the railroad bridge located approximately 560 m upstream of the road bridge. According to Hydro 5 officer, the Telemetry Water Level Gauge used to be at the railroad bridge. However, about 2 years

ago it was relocated to the road bridge due to unsuccessful negotiations with SRT (the State Railway of Thailand) for the site use.

- Discharge measurement is taken more than 20 times per year at the upstream side of the bridge.
- Measurement is taken by using Propeller Current Meter. Measured parameters are velocity and water depth at every 5 m width along the channel cross section. Velocity measurement in z direction (vertical) is taken at 6 locations when water depth is more than 2.5 m, and 3 locations when the depth is less than 2.5 m.
- Telemetry Water Level Gauge collects data every 15 minute. These water level data are sent to the RID office at the Chao Phraya Dam, and then the Chao Phraya Dam office forwards these data to RID Headquarter in Samsen.
- The 2011 H-Q curve consisted of two curves, 1) R-1: from April 1 to October 18, and 2) R-2: after October 19. According to RID officer, the date dividing the curves into two was decided according to the trend shown in the record. Even though discharge in November was lower than 100m^3/s, water level was more than 5 m MSL. This is due to the backwater effect caused by the overflowed water in the downstream reach.

Looking Left Bank from the Railroad Bridge. (Parapet wall is installed on both right and left banks. During the 2011 Flood, the water overflowed these banks, however there was no inundation over the Railroad Bridge as elevation of the bridge abutment was high enough.)

Looking Downstream from the Railroad Bridge where S26 station is installed. The channel is curved right ward looking downstream.

Looking at Left Bank with Parapet Wall from the Railroad Bridge. (Parapet wall is installed on right bank as well. During the 2011 Flood, the water overflowed these banks, however it is assumed that inundation over the railroad bridge was not occurred.)

Right Bank, Looking Downstream of the Railroad Bridge

Propeller Current Meter

Counter and Winch

Looking Upstream from Water Gauge Set Up at the Bridge

Looking Downstream from Water Gauge Set Up at the Bridge

RID Telemetry Water Gauge System

DWR Telemetry Rain-Water Level Gauge System

T1.4.10 C29A (Bang Sai)

C29A station is located at approcimately 115 km upstream of the river mouth, this station is affected by tidal level at the Gulf of Thailand. Due to the tidal effect, adverse current (the river flows the direction from downstream to upstrem) can be observed depending on the river discharge. H-ADCP, a discharge measurement equipment, is installed at this site because the equipments used at other stations are not suitable due to the unique flow condition.

The measaurment method of H-ADCP（Horizontal Acoustic Doppler Current Profiler） which is installed at C29A is summarized as follows.

<table>
<tr><td colspan="2">C29A: Bang Sai (14°9’ 8.28”, 100°30’ 55.96”) Chao Phraya River</td></tr>
<tr><td colspan="2">－RID Hydrological Station is installed at a peir.
－Hydrological Stations of DOR, DWR, and HAII are not installed at this location.
－Due to tidal effect, RID installed H-ADCP to measure velocity and water level at every one hour (Measurement is taken from left bank to right bank).</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>H-ADCP Modem Box</td><td>H-ADCP Modem Box</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>H-ADCP Installation Location</td><td>H-ADCP Installation Location</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Location of Measurement along Cross Section (Approx.500m)</td><td>Water Mark of the 2011 Flood (4.15 m MSL)</td></tr>
</table>

Side Looking: WinH-ADCP

Side Looking: Channel Master WINH-ADCP (TELEDYNE RD Instruments)

Channel Master Horizontal ADCP (TELEDYNE RD Instruments)

Key Specifications: RID apply the equipment with 300kHz and Max Range 300m.

Frequency:	**300 kHz**	**600 kHz**	**1200 kHz**
# Cells:	1 - 128 cells		
Resolution:	0.1 cm/s		
Max Range:	**300m**	90m	20m

Source: Teledyne RDI webpage, http://www.rdinstruments.com/channelmaster.aspx

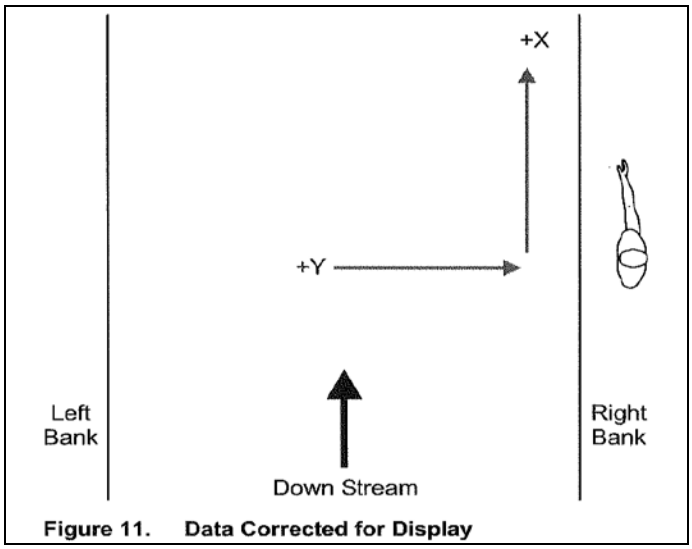
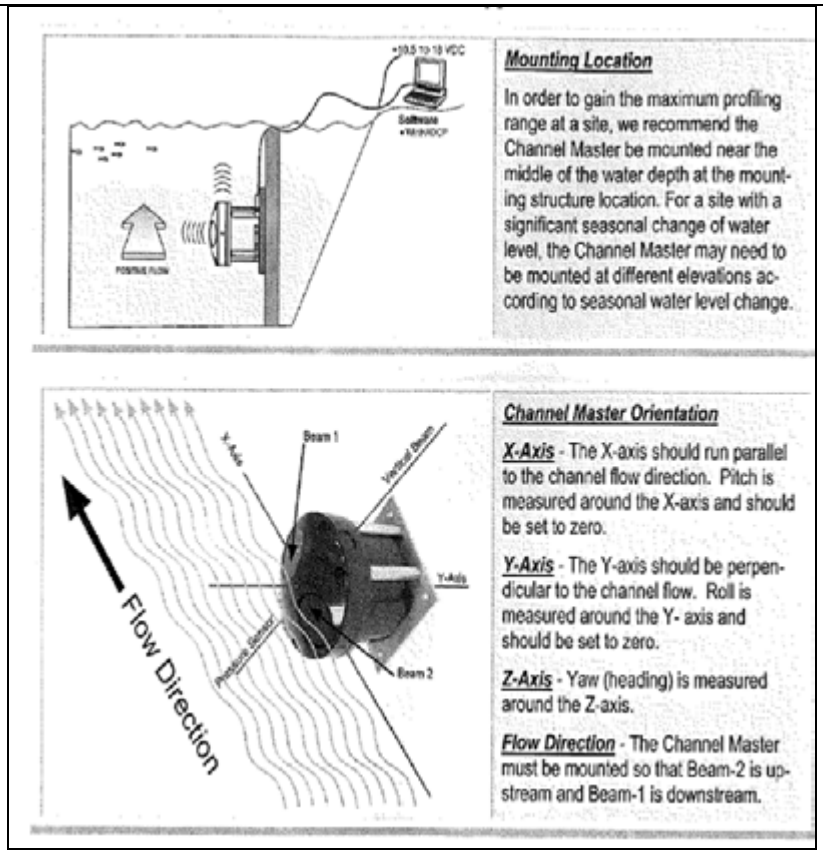


Figure 11. Data Corrected for Display

Source: WinH-ADCP User's Guide, Teledyne RD Instruments



Source: Channel Master Quick Start Guide, TELEDYNE RD Instruments

Horizontal Acoustic Doppler Current Profiler

Technical Specifications

Model Name	CM300	CM600	CM1200
System frequency	300kHz	600kHz	1200kHz
Water Velocity Profiling (Broadband mode)			
Profiling range	4m[a] to 300m[b]	2m[a] to 90m[b]	1m[a] to 25m[b]
Velocity range	±5m/s default, ±20m/s maximum		
Accuracy	±0.5% of water velocity relative to ADCP, ±2mm/s		
Resolution	1mm/s	1mm/s	1mm/s
Number of cells	1-128	1-128	1-128
Cell size	1m to 8m	0.5m to 4m	0.2m to 2m
Blanking distance	1m	0.5m	0.2m
Data output rate	User-programmable		
Physical Properties			
Weight in air	6.8kg	4.76kg	3.4kg
Weight in water	3.17kg	2 kg	1.58kg
Height	18.3cm	18.3cm	18.3cm
Width	32.5cm	26.4cm	18.3cm
Depth	19.8cm	19.3cm	18.9cm
Transducer			
Geometry	2 beams, ±20°	2 beams, ±20°	2 beams, ±20°
Beam width	2.2°	1.5°	1.5°

[a] Assume one good cell (minimum cell size); range measured from the transducer surface.
[b] Assume fresh water; actual range depends on temperature and suspended solids concentration.

Source: http://www.rdinstruments.com/datasheets/channelmaster_ds_lr.pdf

1. Cross-Secion Area (A) by Sonar (Echo Sounding) is measured first, then input the value to H-ADCP.
2. H-ADCP measures water level (H) by Z direction beam whereas velocity by X&Y direction beams. Different from River Surveyor M9, H-ADCP is fixed on a pole in water, specifically fixed at about 6 m from the water surface.
3. Velocity measurement is taken every one hour, then H-ADCP system calculates discharge based on the measured velocity. This discharge will be stored with other measured information in modem which is set up near by the H-ADCP mounted pole. Officer at Hydro 5 centre calculates daily average discharge from the hourly observed data.
4. This station is called as C29A, the observed data (water level and discharge) exists since December 1st, 2007.
5. The previous station is called as C29 which is located about 3 km upstream from C29A.

・No discharge calculation is required.
・H-ADCP has the maximum survey distance of 300m. The river width at C29A is approximately 500 m. The measured data must be calibrated in order to reflect the flow condition in the unmeasured section of 200 m. For the calibration, measurement result of River Surveyor M9 is utilized. (three times per year, simultaneous measurements of River Surveyor M9 and H-ADCP are conducted)**.**

Calibration Method of H-ADCP Data

Calibration Method

- Simultaeous measuremts of H-ADCP and River Surveyor 9 (H-ADCP continuously measures vertically along cross section) are conducted（Refer to Table A）.
- Calculate average of『V_{x1}（Velocity of x direction）』from H-ADCP measurement（Average of per minute measurement by ADCP, refer to Table A）.
- Based on the measured discharge by River Surveyor M9（ADCP） and cross sectional area (A) by H-ADCP,『V_{mean}（mean velocity）』is calculated (Refer to Table B).
- Calculate the correlation between『V_{x1}』and『V_{mean}』（Refer to Table C）. Based on the determined correlation equation, recalculate『V_{mean}』from『V_{x1}』. Then H-ADCP discharge is calculated by『V_{mean} x A_1』.

Table A Simultaneous Measurement: H-ADCP and River Surveyor M9 (September 15th, 2012)

H-ADCP						River Surveyor M9 (ADCP)				
Date & Time	Q_1 (m^3/s)	V_1 (m/s)	H_1 (m)	A_1 (m^2)	V_{x1} (m/s)	Date & Time	Q_2 (m^3/s)	V_2 (m/s)	H_2 (m)	A_2 (m^2)
2555/9/25 15:06	964	0.132	1.876	7,295	0.151	2555/9/25 15:06	1,857	0.261	1.870	7,108
2555/9/25 15:07	952	0.131	1.877	7,295	0.148	-				
2555/9/25 15:08	927	0.127	1.878	7,296	0.146	2555/9/25 15:10				
2555/9/25 15:09	929	0.127	1.878	7,296	0.147					
2555/9/25 15:10	997	0.137	1.878	7,296	0.156					
Average	954	0.131	1.877	7,296	0.150					
2555/9/25 16:09	862	0.118	1.948	7,301	0.136	2555/9/25 16:09	1,466	0.205	1.940	7,147
2555/9/25 16:10	956	0.131	1.940	7,297	0.152	-				
2555/9/25 16:11	968	0.133	1.942	7,298	0.152	2555/9/25 16:14				
2555/9/25 16:12	935	0.128	1.943	7,298	0.147					
2555/9/25 16:13	954	0.131	1.884	7,299	0.151					
2555/9/25 16:14	914	0.125	1.885	7,299	0.147					
Average	931	0.128	1.924	7,299	0.148					
2555/9/25 17:03	952	0.131	1.988	7,295	0.151	2555/9/25 17:03	1,642	0.229	1.980	7,147
2555/9/25 17:04	927	0.127	1.983	7,296	0.148	-				
2555/9/25 17:05	929	0.127	1.987	7,296	0.146	2555/9/25 17:08				
2555/9/25 17:06	997	0.137	1.986	7,296	0.147					
2555/9/25 17:07	862	0.118	1.990	7,301	0.156					
2555/9/25 17:08	956	0.131	1.995	7,297	0.136					
Average	937	0.129	1.988	7,297	0.147					
2555/9/25 18:05	1,013	0.137	2.025	7,369	0.148	2555/9/25 18:05	1,695	0.235	2.020	7,200
2555/9/25 18:06	926	0.126	2.024	7,368	0.146	-				
2555/9/25 18:07	903	0.123	2.025	7,369	0.147	2555/9/25 18:11				
2555/9/25 18:08	910	0.123	2.028	7,370	0.156					
2555/9/25 18:09	905	0.123	2.027	7,370	0.136					
2555/9/25 18:11	848	0.115	2.027	7,370	0.152					
Average	917	0.125	2.026	7,369	0.148					
2555/9/25 19:10	1,147	0.155	2.052	7,392	0.152	2555/9/25 19:10	1,723	0.239	2.050	7,215
2555/9/25 19:11	1,200	0.162	2.056	7,394	0.152	-				
2555/9/25 19:12	1,127	0.152	2.052	7,393	0.147	2555/9/25 19:23				
2555/9/25 19:13	1,098	0.149	2.054	7,394	0.151					
2555/9/25 19:14	930	0.126	2.055	7,394	0.147					
2555/9/25 19:15	958	0.130	2.053	7,393	0.143					
2555/9/25 19:16	742	0.100	2.053	7,393	0.156					
2555/9/25 19:17	991	0.134	2.053	7,393	0.168					
2555/9/25 19:18	1,079	0.146	2.053	7,393	0.184					
2555/9/25 19:19	1,138	0.154	2.056	7,394	0.189					
2555/9/25 19:20	1,130	0.153	2.053	7,393	0.171					
2555/9/25 19:21	1,028	0.139	2.053	7,393	0.125					
2555/9/25 19:22	1,073	0.145	2.052	7,393	0.142					
2555/9/25 19:23	1,112	0.150	2.055	7,394	0.136					
Average	1,054	0.143	2.054	7,393	0.155					
2555/9/25 22:03	958	0.130	2.072	7,393	0.139	2555/9/25 22:03	1,787	0.248	2.070	7,210
2555/9/25 22:04	1,091	0.148	2.073	7,393	0.159	-				
2555/9/25 22:05	1,114	0.151	2.072	7,393	0.164	2555/9/25 22:11				
2555/9/25 22:06	1,114	0.151	2.072	7,392	0.162					
2555/9/25 22:07	1,192	0.161	2.072	7,392	0.174					
2555/9/25 22:08	1,125	0.152	2.072	7,393	0.165					
2555/9/25 22:09	981	0.133	2.073	7,393	0.144					
2555/9/25 22:10	930	0.126	2.073	7,393	0.138					
2555/9/25 22:11	1,045	0.141	2.072	7,393	0.153					
Average	1,061	0.144	2.072	7,393	0.155					
2555/9/26 1:04	1,246	0.169	2.047	7,380	0.182	2555/9/26 1:04	1,902	0.262	2.050	7,251
2555/9/26 1:05	1,413	0.192	2.043	7,378	0.204	-				
2555/9/26 1:06	1,318	0.179	2.045	7,379	0.193	2555/9/26 1:09				
2555/9/26 1:07	1,203	0.163	2.044	7,378	0.178					
2555/9/26 1:08	1,196	0.162	2.041	7,377	0.176					
2555/9/26 1:09	1,239	0.168	2.042	7,377	0.185					
Average	1,269	0.172	2.044	7,378	0.186					
2555/9/26 3:02	1,229	0.167	2.012	7,362	0.181	2555/9/26 3:02	1,907	0.265	2.000	7,188
2555/9/26 3:03	1,242	0.169	2.013	7,363	0.184	-				
2555/9/26 3:04	1,391	0.189	2.013	7,363	0.206	2555/9/26 3:08				
2555/9/26 3:05	1,280	0.174	2.012	7,362	0.189					
2555/9/26 3:06	1,261	0.171	2.012	7,362	0.185					
2555/9/26 3:07	1,237	0.168	2.011	7,362	0.181					
2555/9/26 3:08	1,151	0.156	2.010	7,362	0.167					
Average	1,256	0.171	2.012	7,362	0.185					

Table A Simultaneous Measurement: H-ADCP and River Surveyor M9 (September 25th, 2012）

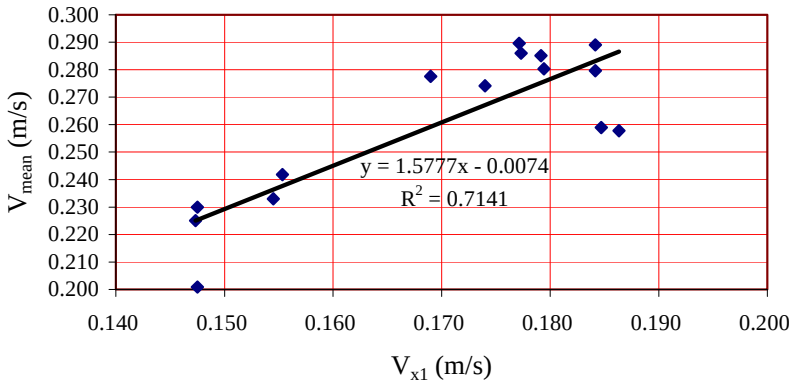
H-ADCP						River Surveyor M9 (ADCP)				
2555/9/26 5:59	1,059	0.144	1.944	7,329	0.162	2555/9/26 5:59	2,009	0.280	1.950	7,177
2555/9/26 6:00	1,087	0.148	1.946	7,330	0.164	-				
2555/9/26 6:01	1,169	0.159	1.944	7,328	0.177	2555/9/26 6:05				
2555/9/26 6:02	1,222	0.167	1.946	7,329	0.184					
2555/9/26 6:03	1,174	0.160	1.945	7,329	0.176					
2555/9/26 6:04	1,184	0.162	1.944	7,329	0.178					
2555/9/26 6:05	1,175	0.160	1.944	7,329	0.177					
Average	1,153	0.157	1.945	7,329	0.174					
2555/9/26 7:02	1,269	0.173	1.921	7,317	0.192	2555/9/26 7:02	2,046	0.287	1.930	7,141
2555/9/26 7:03	1,176	0.161	1.920	7,317	0.177	-				
2555/9/26 7:04	1,194	0.163	1.917	7,315	0.180	2555/9/26 7:07				
2555/9/26 7:05	1,351	0.185	1.916	7,315	0.201					
2555/9/26 7:06	1,236	0.169	1.921	7,317	0.185					
2555/9/26 7:07	1,129	0.154	1.919	7,316	0.170					
Average	1,226	0.168	1.919	7,316	0.184					
2555/9/26 7:57	1,082	0.148	1.894	7,304	0.161	2555/9/26 7:57	2,047	0.289	1.900	7,084
2555/9/26 7:58	1,166	0.160	1.893	7,304	0.175	-				
2555/9/26 7:59	1,217	0.167	1.895	7,304	0.187	2555/9/26 8:03				
2555/9/26 8:00	1,103	0.151	1.892	7,303	0.170					
2555/9/26 8:01	1,206	0.165	1.892	7,303	0.184					
2555/9/26 8:02	1,195	0.164	1.893	7,304	0.185					
2555/9/26 8:03	1,270	0.174	1.892	7,303	0.194					
Average	1,177	0.161	1.893	7,303	0.179					
2555/9/26 9:12	1,310	0.180	1.860	7,287	0.192	2555/9/26 9:12	2,106	0.296	1.860	7,122
2555/9/26 9:13	1,322	0.181	1.855	7,285	0.177	-				
2555/9/26 9:15	1,284	0.176	1.858	7,286	0.180	2555/9/26 9:18				
2555/9/26 9:16	1,272	0.175	1.856	7,285	0.201					
2555/9/26 9:17	1,229	0.169	1.856	7,285	0.185					
2555/9/26 9:18	1,172	0.161	1.855	7,285	0.170					
Average	1,265	0.174	1.857	7,286	0.184					
2555/9/26 10:11	1,239	0.170	1.827	7,271	0.191	2555/9/26 10:11	2,076	0.293	1.830	7,077
2555/9/26 10:12	1,248	0.172	1.825	7,270	0.191	-				
2555/9/26 10:13	1,180	0.162	1.823	7,269	0.181	2555/9/26 10:16				
2555/9/26 10:14	1,062	0.146	1.823	7,269	0.166					
2555/9/26 10:15	1,166	0.160	1.822	7,269	0.181					
2555/9/26 10:16	990	0.136	1.822	7,268	0.154					
Average	1,148	0.158	1.824	7,269	0.177					
2555/9/26 11:14	1,106	0.152	1.800	7,258	0.171	2555/9/26 11:14	2,102	0.296	1.800	7,105
2555/9/26 11:16	1,065	0.147	1.797	7,256	0.164	-				
2555/9/26 11:17	1,145	0.158	1.799	7,257	0.175	2555/9/26 11:21				
2555/9/26 11:18	1,157	0.159	1.797	7,256	0.177					
2555/9/26 11:19	1,152	0.159	1.794	7,255	0.177					
2555/9/26 11:20	1,090	0.150	1.797	7,256	0.166					
2555/9/26 11:21	1,184	0.163	1.797	7,256	0.179					
Average	1,128	0.155	1.797	7,256	0.173					
2555/9/26 13:02	1,205	0.166	1.759	7,237	0.183	2555/9/26 13:02	2,063	0.292	1.760	7,077
2555/9/26 13:03	1,249	0.173	1.759	7,237	0.189	-				
2555/9/26 13:04	1,172	0.162	1.760	7,238	0.179	2555/9/26 13:07				
2555/9/26 13:05	1,137	0.157	1.759	7,237	0.177					
2555/9/26 13:06	1,196	0.165	1.759	7,237	0.185					
2555/9/26 13:07	1,047	0.145	1.757	7,236	0.162					
Average	1,168	0.161	1.759	7,237	0.179					
2555/9/26 14:05	1,072	0.148	1.757	7,236	0.167	2555/9/26 14:05	2,008	0.285	1.750	7,048
2555/9/26 14:06	1,139	0.157	1.758	7,237	0.176	-				
2555/9/26 14:07	1,114	0.154	1.752	7,234	0.171	2555/9/26 14:11				
2555/9/26 14:08	1,114	0.154	1.755	7,235	0.173					
2555/9/26 14:10	1,042	0.144	1.758	7,237	0.162					
2555/9/26 14:11	1,063	0.147	1.756	7,236	0.165					
Average	1,091	0.151	1.756	7,236	0.169					
2555/9/26 14:56	974	0.134	1.774	7,245	0.151	2555/9/26 14:56	1,846	0.263	1.770	7,011
2555/9/26 14:57	921	0.127	1.775	7,245	0.142	-				
2555/9/26 14:58	997	0.138	1.775	7,245	0.155	2555/9/26 15:01				
2555/9/26 14:59	959	0.132	1.777	7,246	0.152					
2555/9/26 15:00	889	0.123	1.777	7,246	0.141					
2555/9/26 15:01	965	0.133	1.777	7,246	0.151					
Average	951	0.131	1.776	7,246	0.149					

Table B V_{mean} Calculated from Measurements of H-ADCP and River Surveyor M9 (September 25th, 2012)

No.	H-ADCP					River Surveyor M9 (ADCP)				Caculation of Vmean		
	Q_1 (m^3/s)	V_1 (m/s)	H_1 (m)	A_1 (m^2)	V_{x1} (m/s)	Q_2 (m^3/s)	V_2 (m/s)	H_2 (m)	A_2 (m^2)	Q_2 (m^3/s)	A1 (m^2)	V mean (m/s)
1	954	0.131	1.88	7,296	0.150	1,857	0.261	1.87	7,108	1,857	7,296	0.254
2	931	0.128	1.92	7,299	0.148	1,466	0.205	1.94	7,147	1,466	7,299	0.201
3	937	0.129	1.99	7,297	0.147	1,642	0.229	1.98	7,147	1,642	7,297	0.225
4	917	0.125	2.03	7,369	0.148	1,695	0.235	2.02	7,200	1,695	7,369	0.230
5	1,054	0.143	2.05	7,393	0.155	1,723	0.239	2.05	7,215	1,723	7,393	0.233
6	1,061	0.144	2.07	7,393	0.155	1,787	0.248	2.07	7,210	1,787	7,393	0.242
7	1,269	0.172	2.04	7,378	0.186	1,902	0.262	2.05	7,251	1,902	7,378	0.258
8	1,256	0.171	2.01	7,362	0.185	1,907	0.265	2.00	7,188	1,907	7,362	0.259
9	1,153	0.157	1.94	7,329	0.174	2,009	0.280	1.95	7,177	2,009	7,329	0.274
10	1,226	0.168	1.92	7,316	0.184	2,046	0.287	1.93	7,141	2,046	7,316	0.280
11	1,177	0.161	1.89	7,303	0.179	2,047	0.289	1.90	7,084	2,047	7,303	0.280
12	1,265	0.174	1.86	7,286	0.184	2,106	0.296	1.86	7,122	2,106	7,286	0.289
13	1,148	0.158	1.82	7,269	0.177	2,076	0.293	1.83	7,077	2,076	7,269	0.286
14	1,128	0.155	1.80	7,256	0.173	2,102	0.296	1.8	7,105	2,102	7,256	0.290
15	1,168	0.161	1.76	7,237	0.179	2,063	0.292	1.76	7,077	2,063	7,237	0.285
16	1,091	0.151	1.76	7,236	0.169	2,008	0.285	1.75	7,048	2,008	7,236	0.278
17	951	0.131	1.78	7,246	0.149	1,846	0.263	1.77	7,011	1,846	7,246	0.255

Table C Correlation of "V_{x1}" and "V_{mean}" (September 25th, 2012)

No.	V_{x1} (m/s)	V_{mean} (m/s)
1	0.150	0.254
2	0.148	0.201
3	0.147	0.225
4	0.148	0.230
5	0.155	0.233
6	0.155	0.242
7	0.186	0.258
8	0.185	0.259
9	0.174	0.274
10	0.184	0.280
11	0.179	0.280
12	0.184	0.289
13	0.177	0.286
14	0.177	0.290
15	0.179	0.285
16	0.169	0.278
17	0.149	0.255



Recorded Data by H-ADCP at C29A are summarized below.

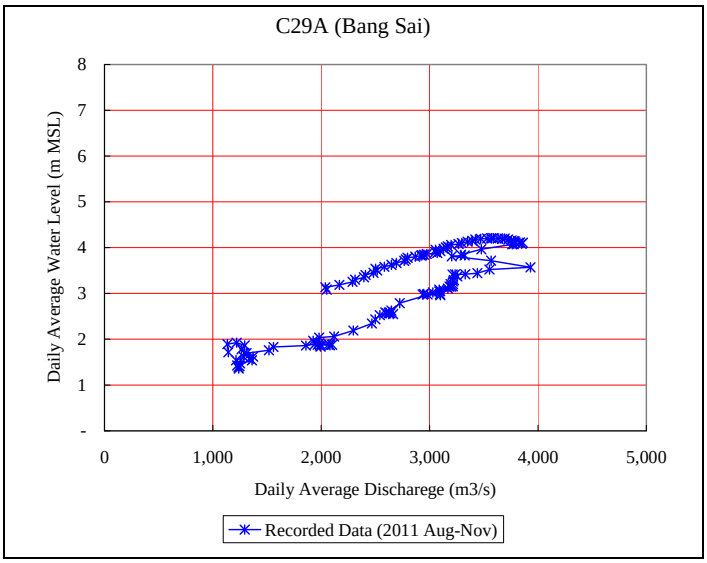
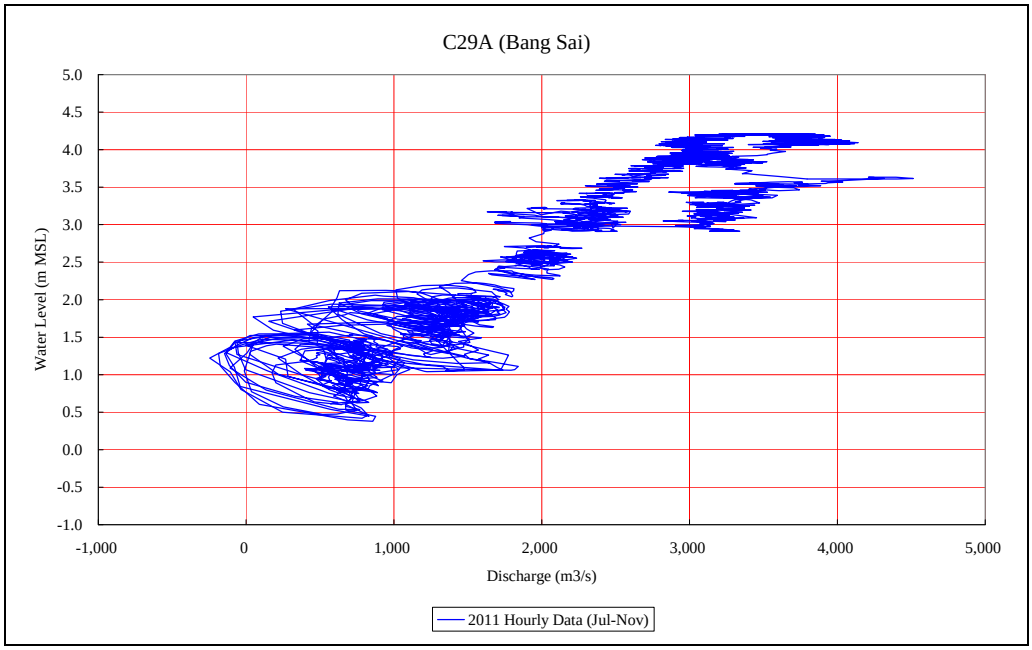
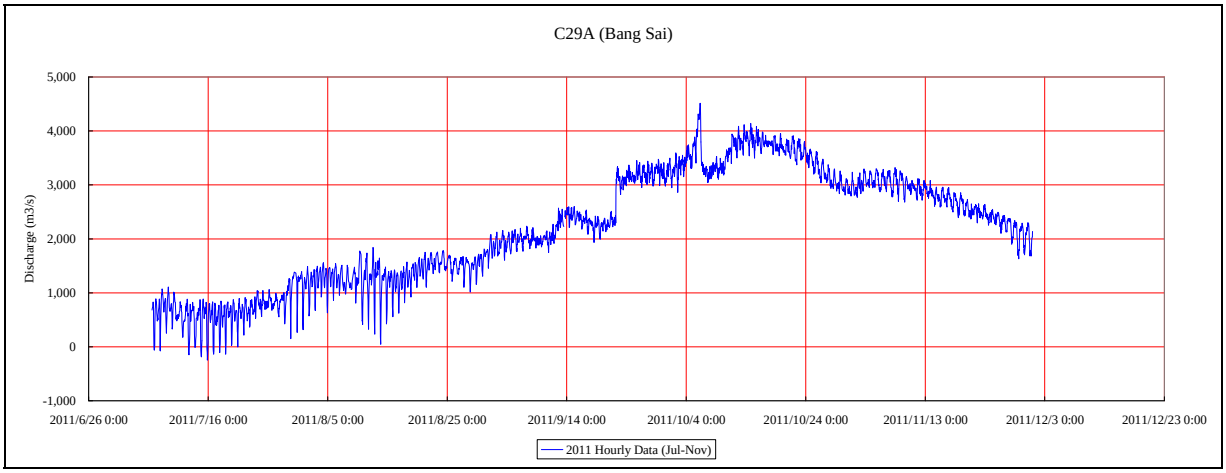


Figure T1.4.37 Recorded Data at C29A (Bang Sai) (Daily Averaged Water Level)





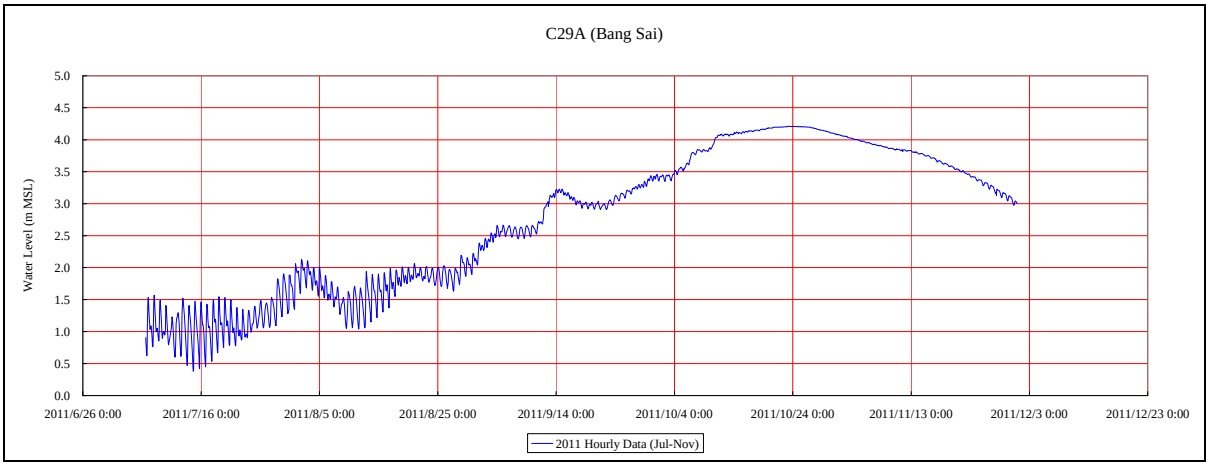


Figure T1.4.38 Hourly Water Level and Discharge at C29A (Bang Sai) in 2011

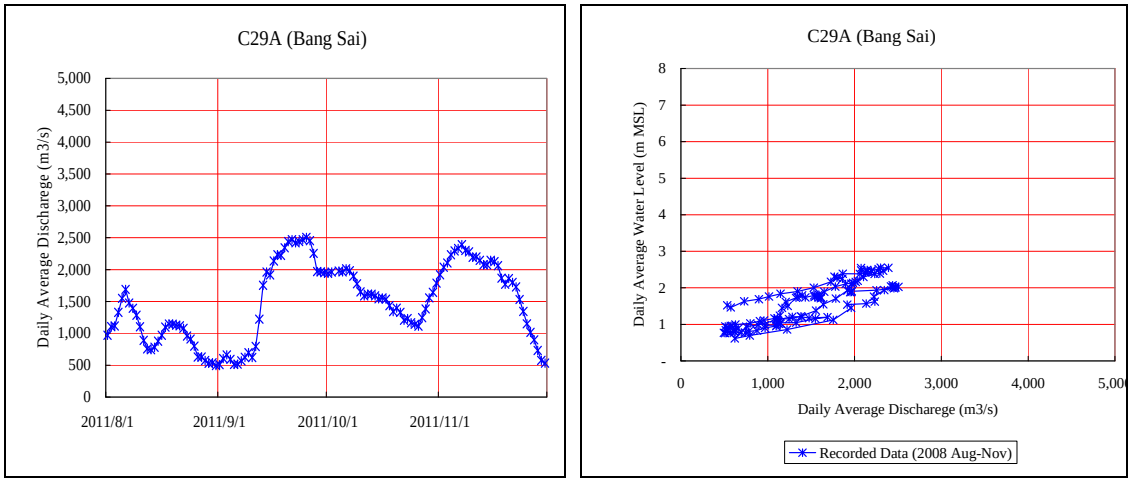


Figure T1.4.39 Daily Averaged Water Level and Discharge at C29A (Bang Sai) in 2008

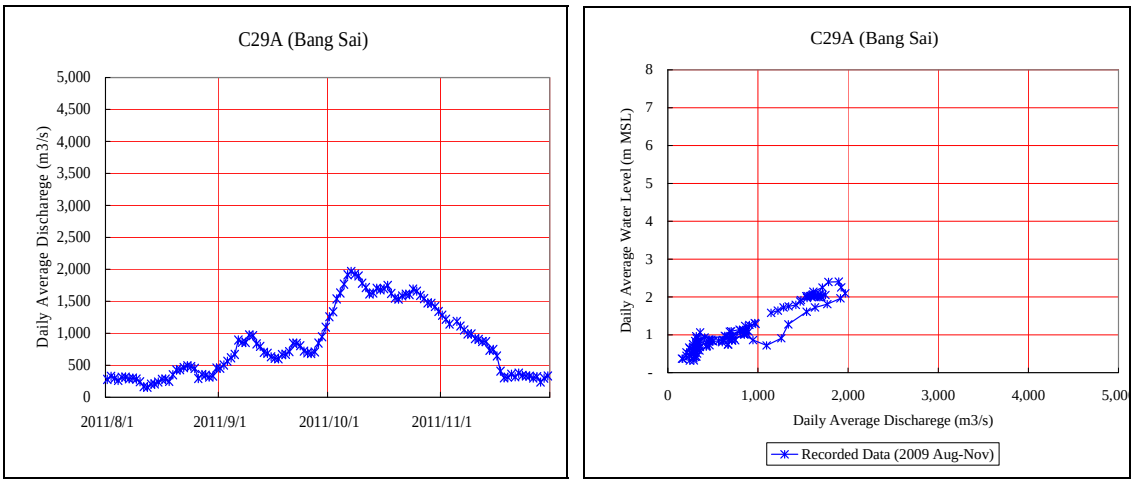


Figure T1.4.40 Daily Averaged Water Level and Discharge at C29A (Bang Sai) in 2009

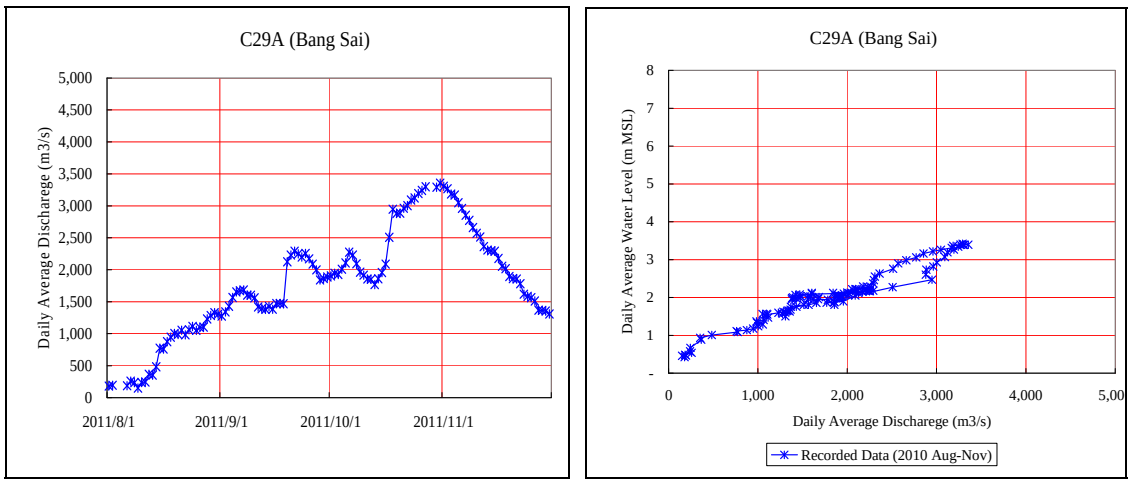


Figure T1.4.41 Daily Averaged Water Level and Discharge at C29A (Bang Sai) in 2010

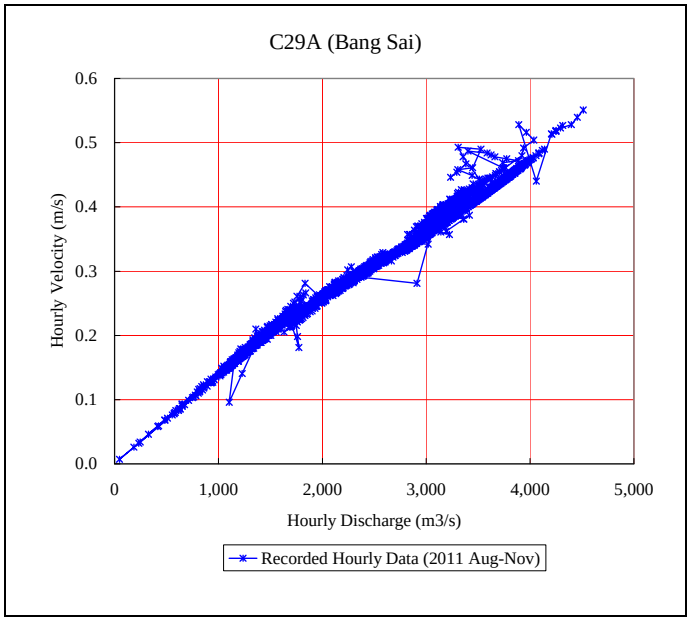


Figure T1.4.42 Hourly Velocity Measurement by H-Q Survey at C29 (Bang Sai)

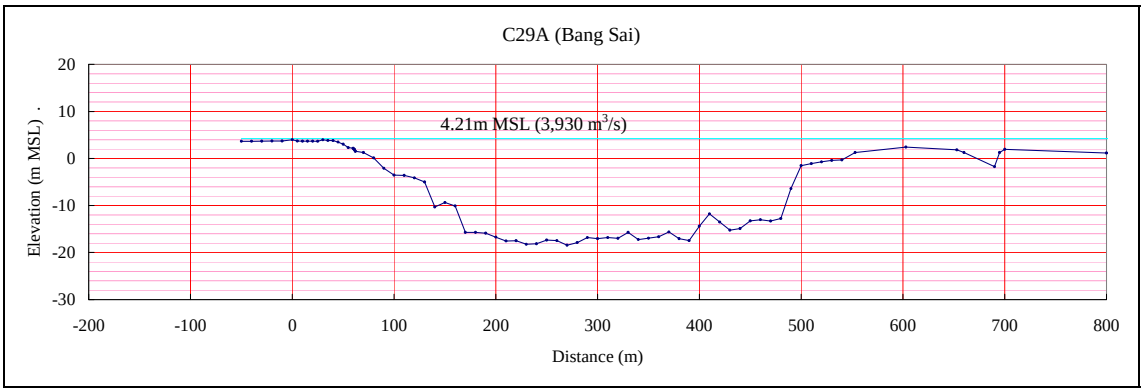


Figure T1.4.43 Cross Section of H-Q Survey at C29 (Bang Sai)

(1) The Recorded Data in 2011 is based on the measurement of H-Q automatic measurement results collected by H-ADCP. This is a new technology used for river discharge measurement. In Japan, this technology is applied for measurements of Arakawa River, Turumi River, Edo River and Sagara River etc. H-ADCP continuously measures discharge along the pre-set cross section. At C29, the calibration is conducted three times per year by taking simultaneous measurements with ADCP (River Surveyor M9). However, it is difficult to conclude whether this calibration method is reasonable or not.

(2) The peak discharge in 2011 at C29A was 3,930 m^3/s. It must be noted that this peak discharge is considered to be much smaller than the actual discharge occurred during the 2011 Flood. According to the RID record, the top elevation of the river bank is approximately 2.4 to 3.7m MSL. During the 2011 Flood, the maximum water level was 4.21 m MSL, which indicates that the water overflowed banks in adjacent areas. However, the maximum width of water surface from H-Q Survey was 550 m, roughly equal to the water surface width at bankfull flow. The peak discharge of 3,930 m^3/s was calculated based on the water volume only within the channel (which means this record is not taking into account the volume of overflowed water). Therefore, it is concluded that the actual peak discharge could be much larger than the record of peak discharge of 3,930 m^3/s.